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NEW TECHNOLOGY

AND

INTERNATIONAL TRADE

by

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A THESIS

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FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled NEW TECHNOLOGY AND INTERNATIONAL TRADE submitted by Paul Lawrence Precht in partial fulfilment of the requirements for the degree of

Abstract

The Heckscher-Ohlin theorem has been found inadequate in explaining trade patterns in highly manufactured commodities. The technological gap theory has been recently advanced as an explanation of trade among the 'footloose' manufacturing industries. This thesis attempts to gauge the role of new technology in Canada's trade of manufactures by examining the labor skill requirements in Canada's exports of manufactures. The results indicate that the secondary manufacturing industries in Canada which possess the greatest international competitive strength are also those engaged most strongly in the development of new technology.

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INTRODUCTION

Towards the close of his initial article on factor price equalization, Samuelson made the comment that

> factor proportions explain only part of the facts of international economics. We must set up hypotheses of differences in international production and productivity, differences in effectiveness which are to be accepted as empirical facts even if not simply explainable.[1]

This statement offers a very succinct summary of the problem to be discussed in this thesis.

The Heckscher-Ohlin theorem has been the most basic and widely acceptable approach to explaining patterns of international trade. The theorem, especially as developed by Samuelson, possesses a logical precision far surpassing that of any of the theories which preceded it or seek to replace it as an explanation of trade patterns. However, a theory may be logically consistent but still fail to reflect accurately the real economic world with which it is concerned.

Corden states in his survey of <u>Recent Developments in the Theory of International Trade</u> that

> recently, as trade between industrial countries has grown, there has been increasing dissatisfaction with the patent inability of the Heckscher-Ohlin model to explain the patterns of trade in manufactured goods.[2]

In the first chapter the essence of the Heckscher-Ohlin theorem and some of its ramifications are outlined and some of the related

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1 P. A. Samuelson, "International Trade and the Equalization of Factor Prices," <u>Economic Journal</u>, 58 (June, 1948), pp. 182-83.

2 W. M. Corden, <u>Recent Developments in the Theory of International Trade</u>, Special Papers in International Economics, No. 7, (Princeton: Princeton University Press, 1965), p. 3.

empirical investigations are reviewed. It is largely out of the testing of the theorem that criticisms of it and the search for more satisfactory alternatives have arisen.

The dissatisfaction with the Heckscher-Ohlin theorem with respect to manufactured goods has not been fruitless. Of the many attempts to fill the void left by the Heckscher-Ohlin theorem has evolved, perhaps in a somewhat piecemeal fashion, the technological gap theory and its concomitant the product cycle theory. These theories, along with some recent empirical works relating new technology to international trade, are discussed in Chapter Two.

The relevance of the technological gap theory in explaining some recent Canadian trade patterns in manufactured commodities is examined in Chapters Three and Four. In Chapter Three the hypothesis is outlined and the data and testing procedures discussed. In Chapter Four the empirical results are presented with some interpretations and conclusions as to the applicability of the technological gap theory in explaining Canada's trading of manufactured goods.

Chapter One

THE HECKSCHER-OHLIN THEOREM

The Basic Theorem

The Heckscher-Ohlin theorem depends for its logical precision on a set of highly rigorous assumptions. Those assumptions which are necessary for the derivation of the complete Heckscher-Ohlin model are as follows:

1. There are two countries which produce two commodities, both of which are produced before and after trade, using two factors of production; the commodities and factors are of identical quality in both countries.

2. Relative factor endowments differ between the countries, are fixed in supply, and are immobile between the countries.

3. Perfect competition exists in the commodity and factor markets with factors completely mobile within the countries.

4. There are no transport costs, tariffs, or other barriers to trade.

5. The countries have identical, homothetic indifference curves.

6. Each commodity has a different production function which is identical between countries, is linear and homogeneous, is uniquely intensive in one of the factors, and is characterized by a diminishing marginal rate of substitution between the factors.

The conclusion with respect to international trade patterns that is predicated by this model is that a country will export the commodity whose production utilizes intensively its relatively abundant factor. The fundamental difference between countries that determines the structure of trade is the difference in factor endowments. Because factor endowment ratios differ, each country must have a relatively abundant factor. Within the framework specified above the price of the abundant factor is lower than

that of the scarce factor, compared to factor prices in the other country, thus permitting the country to produce the commodity utilizing its abundant factor intensively in its production relatively more cheaply than is possible in the other country, and thereby giving the country a comparative advantage in this commodity. The comparative advantage is reflected in the differing commodity price ratios between the countries, commodity prices being determined by factor prices, and factor prices by factor endowments.[1]

As long as commodity price ratios differ between the countries there will be an incentive to initiate trade, or if trade already exists to increase its volume. Each country exports its relatively cheap commodity, thus producing more of it, while decreasing production of its relatively more expensive commodity which it imports. When equilibrium between the two countries is reached---the trade flow continues to exist but does not increase--the commodity price ratios will be the same in both countries.

Trade increases specialization in production, each country specializing in the production of the commodity utilizing intensively its abundant factor, though specialization is incomplete by assumption. This shift in production places upward pressure on the price of the abundant factor which is used intensively in the expand-

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While the results in a general equilibrium context are achieved simultaneously and instantaneously, there is a market mechanism which brings about these changes which can best be described as a linear chain of causation. As Samuelson points out in "International Trade and the Equalization of Factor Prices Once Again," Economic Journal, 59, (June, 1949), pp. 181-97, the line of reasoning can either be from commodity price ratios to factor price ratios, or vice versa, and still yield the unique relationship between commodity price ratios and factor price ratios.

ing exporting industry and downward pressure on the scarce factor which is used intensively in the contracting importing industry. While the ratio of scarce to abundant factor released by the contracting industry exceeds that being used in the expanding industry, all the factors released can be absorbed because of the changing factor prices. This reduction in the price of the scarce factor means it will be substituted for the abundant factor in both industries, thus increasing the scarce to abundant factor ratio in both industries. As the proportions of scarce factor to abundant factor increase in both industries the marginal product of the former will fall and that of the latter will rise, which must occur when the relatively scarce factor of production becomes cheaper and the relatively abundant factor becomes more expensive. Again, because of differing factor endowments, the relatively scarce factor in the one country will be the abundant factor in the other country, and vice versa, so the factor prices will be converging in the two countries.

Ohlin realized that international trade produced a tendency toward the equalization of factor prices between the two trading countries, but he believed that only a partial equalization of factor prices would occur. Samuelson has subsequently proven that within the assumptions given above there will exist a one-to-one relationship between relative commodity prices and relative factor prices so that the Heckscher-Ohlin theorem implies complete factor

price equalization, relatively and absolutely.[1]

The Heckscher-Ohlin theorem, as outlined above, is a purely static model, dealing with fixed supplies of factors, technology, and tastes for each country. There have been, however, some attempts to introduce some dynamic elements into the Heckscher-Ohlin framework. Rybczynski extended the framework to demonstrate the effect on trade patterns of a change in the supply of one of the factors.[2] He found that if the supply of one factor increased in one of the countries, at constant international terms of trade, there would be an absolute expansion in the production of the commodity utilizing this factor relatively intensively and an absolute reduction in the production of the other commodity. The relative price of the commodity using intensively the factor whose supply has increased will fall. If the assumption of homothetic patterns of consumption is dropped, the extent of the fall in price will depend on the marginal propensity to consume this commodity. If commodity prices are allowed to vary, the country's terms of trade will improve or deteriorate according to whether the commodity which uses intensively the factor whose supply has increased is imported or exported.[3]

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Samuelson, "International Trade and the Equalization of Factor Prices," and "International Trade and the Equalization of Factor Prices Once Again."

2

T. M. Rybczynski, "Factor Endowment and Relative Commodity Prices," Economica, 22 (November, 1955), pp. 336-41.

3

This type of analysis can be extended to consider changes in the supplies of both factors at various proportions. See A. Guha, "Factor and Commodity Prices in an Expanding Economy," Quarterly Journal of Economics, 77 (February, 1963), pp. 149-55.

The impact of technological progress on trade has also been considered within the Heckscher-Ohlin framework.[1] Technological change in this context means not the introduction of new products into the market, but rather a change in the production function. Neutral technical progress, which involves a reduction in the quantity of factors required to produce a given output but with the factors being used in the same proportion as at the initial factor price ratio, increases the output of the industry in which it occurs and reduces output in the other industry at constant commodity price ratios. Biased technical progress alters the optimum ratio at which one factor is employed relative to the other at initial factor prices, thus not only lowering the cost of production in the industry in which it occurs but also releasing a quantity of the factor which it saves. If the technical change is biased toward the factor which that industry employs intensively, at a constant commodity price ratio the output of the industry in which the technical progress occurred must increase, and the output of the other industry must decrease. When the bias in technical progress is toward the factor not employed intensively by the industry, the output of the industry in which the progress occurs will increase, while the output of the other industry may increase or decrease depending on the extent of the bias. It is even more difficult to generalize on

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1 The lead article for analyzing the impact of technological change within the Heckscher-Ohlin framework was that of R. Findlay and H. Grubert, "Factor Intensities, Technological Progress, and the Terms of Trade," <u>Oxford Economic Papers</u>, New Series, 11, (February, 1959), pp. 111-21.

the impact of technological progress on trade patterns when the restriction of homotheticity on the consumer preference set is removed.[1]

While technological progress will alter trade patterns insofar as it alters commodity price ratios between countries--it can even reverse the direction of the trade flow between the countries provided we lift the assumption forbidding factor reversals as well as the assumption of identical technology--it must be emphasized that technological progress itself does not constitute the basis of trade. Trade patterns are still determined by factor endowments, with each country exporting the commodity utilizing its abundant factor intensively. Techniques of production determine which factor will be utilized intensively in the production of a commodity.

The Leontief Paradox

The logical attractiveness of the Heckscher-Ohlin theorem probably accounted for its widespread acceptability in trade theory. The subjection of the theory to empirical investigation, however, led to doubts and dissension as to the applicability of this theory in explaining trade patterns observed in the world.

One of the pioneering attempts to test the Heckscher-Ohlin theorem was conducted by MacDougall, who attempted to determine if the exports of the United States were more capital-intensive than

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The analysis with non-homothetic consumption functions can be found in H. G. Johnson, "Economic Development and International Trade," in Money, Trade, and Economic Growth, (2nd ed. London: George, Allen and Urwin Ltd., 1964), pp. 95-103, and Nobuo Minabe, "The Heckscher-Ohlin Theory, the Leontief Paradox, and Patterns of Economic Growth," American Economic Review, 56, (December, 1966), pp. 1193-1211.

those of the United Kingdom.[1] While his results did not coincide with his expectations--which were based on the Heckscher-Ohlin theorem--his test is generally considered a bit too crude to constitute an adequate refutation of the theory. Apart from other statistical criticisms, his indicator of capital intensity--horse-power utilization--was considered deficient.[2]

Certainly the most famous attempt to subject the logically neat Heckscher-Ohlin theorem to empirical investigation was that undertaken by Leontief with respect to American export and import-competing industries.[3] Leontief assumed a reduction in trade occurring for the United States and observed the factors released by the contracting export industries and those required by the expanding import-competing industries. In addition to determining the factor intensities of commodities exported and imported in testing the Heckscher-Ohlin theorem, on must also determine the factor endowments of the countries under consideration. Leontief neglected to do this, relying instead on the general presumption that the United States is the most capital-abundant country in the wrld. In Leontief's

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1 G. D. A. MacDougall, "British and American Exports: A Study Suggested by the Theorem of Comparative Advantage," Economic Journal, 61, (December, 1951), pp. 697-724.

2 See, M. O. Clement, R. L. Pfister, and R. J. Rothwell, Theoretical Issues in International Economics, (Boston: Mifflin Company, 1967), p. 99.

3 W. W. Leontief, "Domestic Production and Foreign Trade: The American Capital Position Re-examined," Proceedings of the American Philosophical Society, 97, (September, 1953), pp. 332-49.

test the United States' trading partner is the rest of the world, so one would expect the exports of the United States to be capital-intensive commodities and the imports to be labor-intensive, in accord with the Heckscher-Ohlin theorem.

Calculating direct and indirect capital and labor requirements for United States industries from the 1947 imput-output tables, Leontief arrived at the surprising result that with a reduction in trade the exporting industries would release more labor and less capital than required by the import-competing industries. These results do not coincide with the expectations derived from the Heckscher-Ohlin theorem and are commonly referred to as the "Leontief paradox." While the correct statistical procedure is to reject a theory which is contradicted by the facts, there was a strong reluctance to do so in this case because of the apparent plausibility of the Heckscher-Ohlin theorem. There have instead been numerous attempts to reconcile the divergence between the theory and the facts, resulting in some scepticism regarding the ability of the Heckscher-Ohlin theorem to explain trade patterns and some suggestions as to alternative theoretical approaches to trade theory.

There are, in a general sense, two ways of explaining Leontief's paradoxical results. One could argue that the Heckscher-Ohlin model, as outlined in the assumptions above, does not depict the real world with sufficient accuracy, thereby allowing observable trade patterns to differ from those predicted by the theory. While the Heckscher-Ohlin model obviously involves some abstractions, the question to be asked in determining the validity of the theory is whether the

differences between the real world and the abstract world of the Heckscher-Ohlin model are sufficiently important to allow the theoretical and observable results to differ.[1] A related question is whether factor endowment differences between countries, which are isolated in Heckscher-Ohlin model as the crucial determinant of trading patterns, may be exceeded in importance by other differences between countries which are assumed negligible in this model.

Alternatively, one could explain the paradox by arguing that Leontief's statistical analysis was inconsistent with the theory, or otherwise inadequate, thus invalidating the results. Some of the criticisms of Leontief dwelt on such issues as the accuracy of the capital-output ratios used by Leontief for several specific industries, the level of aggregation of the industries used by him, etc.[2] Leontief in a subsequent study attempted to take into account as many of the criticisms of his initial paper as possible, although

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My methodological position with respect to economic theory would be that of the logical positivist, or pragmatic, school whose criterion for the acceptance of an economic theory, according to C. E. Ferguson, is the ability of the theory to predict accurately. Microeconomic Theory, (Homewood, Illinois: Richard D. Irwin, Inc., 1966), pp. 6-7.

2

For some surveys of criticisms and explanations of Leontief's results see Jagdish Bhagwati, "The Pure Theory of International Trade: A Survey," Surveys of Economic Theory, Vol. 2, (New York: St. Martin's Press, 1965), pp. 176, R. E. Caves, Trade and Economic Structure, (Cambridge: Harvard University Press, 1960), pp. 273-281, and Clement, Pfister, and Rothwell, International Economics, pp. 101-04.

he did not alter his basic technique.[1] He achieved again the same perverse results, that the exporting industries of the United States were more labor-intensive than its import-competing industries. While these two ways of explaining the paradox are frequently not entirely separable, I shall attempt to concentrate my attention in this paper on the former types of criticisms.

Leontief himself admitted that the fact that the only factors of productions included in his analysis were labor and capital, and these in a very broad, aggregative sense, may have distorted his results. One explanation of his paradoxical findings which is frequently posited is his failure to distinguish land or natural resources, the third classical factor, as a separate factor of production. Kravis found that capital requirements are much higher in primary industries than in secondary industries, thus leading him to suggest that "the explanation of Leontief's findings lies in the availability of certain natural resources abroad and their growing scarcity at home."[2] It is the scarcity of natural resources in the United States that has caused it to become an importer of high capital requirement commodities, thus accounting for Leontief's conclusion. As a high percentage of American direct foreign invest-

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W. W. Leontief, "Factor Proportions and the Structure of American Trade: Further Theoretical and Empirical Analysis," Review of Economics and Statistics, 38 (November, 1956), pp. 386-407.

2

I. B. Kravis, "'Availability' and Other Influences on the Commodity Composition of Trade," Journal of Political Economy, 64 (April, 1956), p. 150.

ment is in primary industries it is frequently American capital that is used in producing its own imports. Some economists have suggested it may be more appropriate to consider enclaves of foreign capital as part of the investing country.

This relation between capital requirements and natural resource utilization was further corroborated by Vanek who found a negative correlation between labor and natural resource content of commodities but a strong positive correlation between capital and natural resource content.[1] Such a relationship would appear to be highly relevant in explaining Wahl's findings regarding Canadian trade.[2] Using the Leontief technique, he concludes that Canada "engaged in trade to dispose of capital and conserve labor; this is true of Canada's total, Canada-United Kingdom, and Canada-United States trade."[3] Wahl's results are generally considered perverse under the presumption that the Canadian economy is less capital abundant than that of either the United Kingdom or the United States. The

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1
J. Vanek, "The Natural Resource Content of Foreign Trade: 1870 - 1955, and the Relative Abundance of Natural Resources in the United States," Review of Economics and Statistics, 41 (May, 1959), pp. 146-53.

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D. Wahl, "Capital and Labor Requirements for Canada's Foreign Trade," Canadian Journal of Economics and Political Science, 27 (August, 1961), pp. 349-58.

3
Ibid., p. 353.

fact that most Canadian exports are natural resource oriented explains the capital intensity of our exports.[1]

Apart from the possibility that the importance of capital and labor may in some instances be exceeded by that of natural resources, some economists have expressed a few doubts as to the importance of capital at the best of times as a determinant of trade patterns. Ohlin stated that produced means of production not only were not a fundamental feature of a country's factor endowment, but were largely irrelevant to its comparative advantage.[2] Wilkinson, in his monograph explaining recent Canadian trade patterns, expressed the view that "capital is by far the most mobile of the factors of production and consequently tends not to be a major determinant of trade flows."[3] The opinion of Sir Roy Harrod was similar, as he held

> the view that the ratio of the capital/labor endowment had a relatively small effect on the patterns of trade, though it was undoubtedly a big factor for the standard of living and for productivity. He regarded the important thing as being the endowment of other factors of production and especially the natural and human resources of the country in question.[4]

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1 Sixty-five per cent of Canada's exports are manufactured products compared to eighty per cent of her imports; however, these manufactured exports require very minimal fabrication frequently. See B. W. Wilkinson <u>Canada's International Trade: An Analysis of Recent Trends and Patterns</u>, (Montreal: Private Planning Association of Canada, 1968), Ch. 5.

2 See Caves, <u>Trade and Economic Structure</u>, Ch. 4.

3 Wilkinson, <u>Canada's International Trade</u>, p. 107.

4 Sir Roy Harrod and Douglas Hague, editors, <u>International Trade Theory in a Developing World</u>, (London: MacMillan, 1965), p. 393.

Keesing, in a work to be discussed below, found that using United States fixed and total capital coefficients for a group of industries did not offer a satisfactory explanatory device for trade patterns, especially when compared to his results obtained using United States labor skill coefficients.[1]

Perhaps rather than deleting capital entirely as a determinant of international trade, one might consider other aspects of capital than its physical quantity. Ohlin suggested the possibilities of creating new capital goods may have an important influence on trade, a more appropriate indicator of the influence of capital than its physical quantities perhaps being the supply of loanable funds or the technical efficiency of new machines.[2] Kenen, on viewing the difficulty experienced in empirically verifying the Heckscher-Ohlin theorem, contended "that most of these apparent anomalies descend from the <u>simpliste</u> concept of capital used in the factor endowments analysis."[3] He proposed a slight departure from the conventional factor proportions analysis of trade, selecting nature and capital as the two factors of production explaining trade patterns.

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1 D. B. Keesing, "Labor Skills and International Trade: Evaluating Many Trade Flows with a Single Measuring Device," <u>Review of Economics and Statistics</u>, 47 (August, 1965), pp. 287-94.

2 Caves, <u>Trade and Economic Structure</u>, Ch. 4.

3 P. B. Kenen, "Nature, Capital, and Trade," <u>Journal of Political Economy</u>, 73 (October, 1965), p. 438.

He assumes each country is endowed with fixed quantities of land and labor, which together constitute the factor nature and which can be improved by investing in them. He does not envisage capital as entering directly into the production process, but rather it is a 'waiting' period during which the quality of nature is improved. By being embodied in the land and labor, capital is able to contribute to production and thus influence trade patterns. Such a theory, Kenen admits, is not amenable to empirical testing because of the many abstract concepts involved.

Much related to the above forebodings as to the definition given capital when gauging its influence on trade patterns are the potential dangers of considering labor as a homogeneous factor. Leontief suggested that if the superior efficiency of the United States labor force relative to that of other countries were taken into consideration, i. e. measurement of labor endowments in terms of efficiency units, the United States would be a labor-abundant country, thus eliminating the conflict between the Heckscher-Ohlin theorem and his findings. He went further in suggesting that United States labor is three times as efficient as its foreign counterparts. While the factor three is sufficient to make the United States a labor-abundant country, his choice of this factor is quite arbitrary. Kreinen attempted to measure the relative efficiency of the labor force in various countries to determine whether Leontief's explanation of his results was justifiable.[1] Although he found the United

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M. Kreinen, "Comparative Labor Effectiveness ad the Leontief Paradox," American Economic Review, 55, (March, 1965), pp. 131-40.

States labor force to be the most efficient, its superiority was not sufficiently great to make it a labor-abundant country.

Although Leontief's estimate of the superiority of the American labor force has been subsequently disproven by Kreinen, Leontief did present some further results suggesting the existence of qualitative differences between the labor inputs in United States exports and that of United States imports. Rather than relying on his crude assumption that the United States labor force is three times as efficient as that of its trading partners, at the conclusion of his 1956 article Leontief distinguished labor requirements in the production of United States exports and import-competing products by five skill categories:

1. Professional, technical and managerial
2. Clerical, sales and service
3. Craftsmen and foremen
4. Operatives
5. Laborers

By considering the heterogeneity of the labor force he found the excess of man-years incorporated in a million dollars of United States export production compared with that in a million dollars of United States import-competing production to be concentrated in the higher skill categories.[1]

Kenen, along with Yudin, in attempting to follow somewhat the

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[1] Leontief, "Factor Proportions and the Structure of American Trade," p., 399.

lines he suggested above, felt that because skills represent investment in man, if United States capital requirements were recalculated to take into account human capital as well as physical capital, the fact that United States exporting industries employ skilled labor intensively may reveal that its exports are actually capital intensive, thus resolving the paradox.[1] Using, essentially, the skill categories devised by Leontief and considering the income differentials between the skill levels to be the returns to capital, they divide these income differentials by rates of return to obtain estimates of the human capital embodied in the various skill categories.[2] In every case the exporting industries employ human capital more intensively than the import-competing industries. After combining tangible and human capital requirements and observing the gap between capital requirements of the exporting industries and that of the import-competing industries, they concluded that "none of these results succeeds in overturning the Leontief paradox, but all of these narrow the very wide difference in capital intensities obtained by considering tangible rather than tangible and human capital."[3]

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P. B. Kenen and Elinor B. Yudin, <u>Skills, Human Capital, and U. S. Foreign Trade Variations on a Theme by Leontief</u>, International Economics Workshop (New York: Columbia University, 1965).

2

The rates of return used are 9 per cent and 12.7 per cent obtained from J. Mincer, "On-the-Job Training: Costs, Returns and Some Implications," and 11 per cent from Gary S. Becker, Underinvestment in College Education." Both are cited in Kenen and Yudin, <u>Skills, Human Capital, and U. S. Foreign Trade</u>, pp. 4 and 14, respectively.

3

<u>ibid</u>., p. 31.

Roskamp and McMeekin found that the capital/labor index for West Germany, derived along Leontief lines, was slightly capital intensive and was about midway between that of the United States and that of Japan, they being labor intensive and capital intensive, respectively.[1] This, they felt was quite incredible as labor was more abundant than capital in West Germany. All of these countries were augmenting their abundant factor rather than scarce factor through trade. They felt these paradoxical findings were likely due to some shortcomings in the definitions of capital and labor used in the studies. More specifically, measuring labor inputs in terms of man-years is inadequate as qualitative differences in labor are not revealed. Roskamp and McMeekin introduced human capital as a third factor of production by looking at labor inputs in terms of labor incomes rather than man-years. Choosing a certain wage rate as the return to 'simple labor' all income above this was considered as a return to human capital. Considering the partial indexes between physical capital and labor, human capital and labor, and human capital and physical capital, they found that while lbor was more abundant than physical capital, human capital was more abundant than either labor or physical capital. Thus they conclude that

> the Leontief Paradox for West Germany is explained by the definition of labor and capital as factors of production. It disappears when human capital is introduced as a third factor of production.[2]

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K. W. Roskamp and G. C. McMeekin, "Factor Proportions, Human Capital and Foreign Trade: The Case of West Germany Reconsidered", Quarterly Journal of Economics, 82 (February, 1968), pp. 152-60.

2

Ibid., p. 160.

In the controversy arising out of Leontief's paradoxical findings, among the most popular themes arising are those stressing the relevance of technological changes and qualitative differences in factors, especially the factor labor which is the source of technological change. Krüeger, in estimating the contribution of various factors of production to per capita income differences between countries, considered three variables normally associated with the concept of human capital --age, educational attainment, and rural-urban distribution--and found that "the differences in human resources between the United States and the less developed countries accounts for more of the difference in per capita income than all other factors combined."[1] Before focusing somewhat more intently on the impact of technological change on international trade, I would like to consider some more recent empirical investigations of the Heckscher-Ohlin theorem which are based on the heterogeniety of the labor force.

Keesing's Consideration of Labor Skills

While Keesing at no point states the theoretical derivation of his empirical studies, his initial work may be regarded as an implicit testing of the Heckscher-Ohlin theorem. Instead of differences in relative endowments of labor and capital between countries, he is concerned with the heterogeous composition of the labor force, considering differences in relative skill endowments between countries to be the dominating influence on trade patterns. His hypothesis is "that the availability of labor skills determines patterns of international location and

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[1] A. O. Krueger, "Factor Endowments and Per Capita Income Differences Among Countries," Economic Journal, 78 (September, 1968), p. 685.

trade for a broad group of manufactured products."[1] His test does not comprehensively include all traded commodities, but rather is applicable only to those not strongly oriented towards natural resources. He based his hypothesis on two observations. First, "direct capital requirements are not as high in manufacturing as in most other activities."[2] It was pointed out above that Kravis and Vanek found capital requirements higher in natural resource oriented industries than in manufacturing industries. Secondly, "labor appears to be less mobile internationally than liquid capital goods."[3] The importance of capital as a determinant of trade patterns has already been brought into question in the preceding section. Some of the reasons for the relative stability of the skill composition of the labor force are discussed at length in a later article by Keesing.[4]

In testing this hypothesis Keesing calculated the labor skill requirements, in man-years per million dollars value added, of the exports and imports in fifteen footloose manufacturing industries

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1 Keesing, "Labor Skills and International Trade," p. 287.

2 Ibid., p. 287.

3 Ibid., p. 287.

4 D. B. Keesing, "Labor Skills and Comparative Advantage, American Economic Review, Papers and Proceedings, 56 (May, 1956), pp. 249-58. Harry Johnson, while not disputing Keesing's conclusions, does not find Keesing's theoretical arguments to be highly convincing. See his "Discussion," American Economic Review, Papers and Proceedings, 1966, pp. 280-283.

of nine leading industrial countries.[1] His subdivision of the labor force into skill categories was the same as that used by Leontief:

1. Professional, technical, and managerial
2. Craftsmen and foremen (skilled manual workers)
3. Clerical, sales, and service
4. Operative (semi-skilled)
5. Laborers (unskilled)

Rather than attempting such a formidable task as calculating the skill requirements for these fifteen industries in each of the nine countries involved, Keesing assumed

> that all manufactured goods traded, not only by the United States but by all other countries as well, are produced with a single set of technical coefficients, namely those used in the United States.[2]

While admitting that an industry does not use identical factor combinations in all countries, he nevertheless felt the assumption that reversals of factor intensities do not occur for an industry between countries, which is a fundamental assumption for the validity of the Heckscher-Ohlin theorem, was justifiable, and offered two alternative lines of rationalizing his adoption of this assumption. Capital and unskilled labor can be substituted for each other, but neither can be substituted for skilled labor, so the United States skill coefficients must reflect the industry's basic skill require-

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1 Canada is not included in these calculations presumably because, as indicated in his footnote number 11, he feels the predominance of natural resource oriented products in Canadian exports may cause our exports of manufactured goods to be determined by complementarities, thus relegating labor skills to secondary importance.

2 Keesing, "Labor Skills and International Trade," p. 287.

ments. Or, skilled and unskilled labor may be substituted for each other so long as the skill requirements are not reversed between industries. It was remarked on in the preceding section that reversals of factor intensities could cause a paradox such as that discovered by Leontief to occur. The results of Minhas strongly suggested that factor intensity reversals were a frequently occurring phenomenon.[1] Minhas' findings, however, have not been accepted as decisive and the issue of factor reversals occurring is still subject to considerable controversy.[2]

Keesing's results appear to support his hypothesis very strongly. He finds that of the nine countries included the United States has the highest skill ratio-skill ratio being defined as Class 1 and 11 requirements divided by Class 1V and V requirements--in its exports and the lowest in its imports, while the opposite holds for Japan.[3] Perhaps most revealing of the differences in the skill compositions of the manufactured goods traded by the nine countries are the ratios of the export skill ratio to the import skill ratio for each commodity, which range from 1.724 for the United States to .374 for Japan.[4]

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1 B. S. Minhas, An International Comparison of Factor Costs and Factor Use, (Amsterdam: North Holland, 1963).

2 See, for example, Joan Robinson, "Factor Prices Not Equalized," Quarterly Journal of Economics, 78 (May, 1964), pp. 202-07, W. W. Leontief, "An International Comparison of Factor Costs and Factor Use: A Review Article," American Economic Review, 54 (June, 1964), pp. 335-45, and D. S. Ball "Factor Intensity Reversals in International Comparison of Factor Costs and Factor Use," Journal of Political Economy, 74 (February, 1966), pp. 77-80.

3 Keesing, "Labor Skills and International Trade," Tables 1 and 2.

4 Ibid., Table 3.

It is Keesing's view that differences in labor skill endowments in the nine countries are reflected in the composition of the exports and imports of these countries. While the results seem very plausible, Keesing's test, like Leontief's, is incomplete in that he makes no attempt to measure the actual endowments of labor skills in the nine countries. If the United States is the most abundantly endowed, relatively as well as absolutely, with skilled labor, and Japan the least, then the results do conform to the Heckscher-Ohlin hypothesis. Moreover, those countries whose exports are skill-intensive import commodities which are unskilled labor-intensive.

Keesing's subsequent article is in some respects an expansion of his initial study.[1] Employing the same basic technique of applying United States skill coefficients to the commodities traded by all countries included in the study, Keesing expanded the number of countries to fourteen, now including Canada, and divided the labor force into eight rather than five skill categories with the additional subdivision being concentrated in the higher skill categories. Rather than looking at only fifteen footloose manufacturing industries, he included forty-six industries this time, thirty-five of which he considered to be footloose while the remaining eleven involved natural resource processing.

The results again revealed differences in the skill requirements of the commodities exported by and imported by the fourteen countries. Canada has the second highest requirements, surpassed only

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1 Keesing, "Labor Skills and Comparative Advantage."

by the United States, of scientists and engineers in her exports and the fourth highest, exceeded by Japan, India and Italy, in her imports. The fact that Canadian imports are so highly skill-intensive can be understood in light of the circumstances that Canada has a very small secondary manufacturing sector in terms of its entire output, in comparison with the other industrialized countries, combined with an extremely high standard of living. Thus most of Canada's imports are secondary manufactures which are the most skill intensive commodities.

In that article Keesing reported some further empirical investigations, with respect to the trade of the United States only, which again indicated the importance of the skill composition of the labor force in determining trade patterns, but created some ambiguity as to the theoretical explanations of his results. In his Table 3, Keesing has calculated the simple linear and Spearman rank correlation coefficients between the percentage of employment in each skill category for each industry and an indicator of the industry's competitive power in trade, the indicator used here being the 1962 United States exports as a percentage of the total exports for each industry of the fourteen countries included in his Tables 1 and 2.[1] The correlations confirm that labor skills are more important in determining trade patterns, for the United States, in secondary manufacturing industries than in resource processing industries. In considering all forty-six industries, ten of the sixteen correlation coefficients are statistically significant, whereas in consider-

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1 *Ibid.*, p. 256.

ing only the thrity-five footloose manufacturing industries thirteen of the sixteen coefficients are statistically significant and all of the coefficients increased in absolute size. For the United States the skill category most strongly associated with trade competitive power is scientists and engineers, with technicians and draftsmen and other professionals close behind. United States exports are negatively correlated with unskilled labor. Keesing concluded that "these correlations confirm that U. S. comparative advantage centers in industries involving a high percentage of professional labor and a low percentage of unskilled labor."[1]

On the basis of the Heckscher-Ohlin theorem we would expect the signs of these correlation coefficients for countries such as India, and Hong Kong, and perhaps Japan, to be opposite to those found for the United States, as their comparative advantage will center in industries using their relatively abundant factor, unskilled labor, relatively intensively. However, the question legitimately arises at this juncture as to whether the high positive correlations between export performance and employment of skilled labor is merely due to the fact that skilled labor is relatively more abundant in the United States, or whether the positive correlations derive from some inherent characteristics of skilled labor which tend to make those industries employing relatively greater amounts of it more competitive regardless of environment. The latter possibility sug-

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Ibid., p. 254-56.

gests that highly skilled manpower by its creative potential instills some dynamic characteristics into the industry in which it is employed, which enable that industry to remain competitive in a world of changing production techniques and consumption patterns. If it is true that Keesing's correlations suggest something more than the relative abundance or scarcity of certain factors of production, then we would expect the signs of the correlation coefficients to remain the same regardless of what country's trade patterns are being investigated.

The consideration of qualitative aspects of a country's labor force, says Harry Johnson,

> is embarrassingly suggestive, since superior labor quality may reflect superior technology, the exploitation of economics of scale, or the possession of superior skills acquired by the investment of resources in the creation of human capital.[1]

It is with the implications of quality differences in labor that the remainder of this paper is concerned.

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1 H. G. Johnson, Comparative Cost and Commercial Policy Theory for a Developing World Economy, The Wicksell Lectures for 1968, Ch. 1, p. 7.

Chapter Two

THE TECHNOLOGICAL GAP THEORY

Footloose Manufacturing Industries

Leontief, in discussing the importance of his findings regarding the labor skill composition of United States trade, concluded that

> the very high productivity of American--as compared with foreign--labor plays a decisive role in the determination of the composition of those United States exports and imports which do not reflect directly the presence or absence in this country of certain natural resources.[1]

He considered labor skills to be an important determinant of trade patterns, but only in those commodities whose production was not closely attached to natural resources. In considering the technological gap theory of trade it is important that those portions of international trade to which new technology is relevant be delineated, and that the discussion be confined to these industries.

In a similar vein to the above quotation from Leontief, Keesing asserted that empirical tests of the relationship between labor skills and international trade "applied only to trade in products of manufacturing activities that are not closely tied to natural resources."[2] A distinction between products tied closely to natural resources and those not is frequently encountered in more recent explanations of

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1 Leontief, "Factor Proportions and the Structure of American Trade," p. 399.

2 Keesing, "Labor Skills and International Trade," p. 288.

international trade. Kravis, in his 'availability' theory, emphasized the availability of natural resources in explaining trade patterns in primary commodities and the availability of technological progress and product differentiation as determinants of trade in products in the more advanced stages of fabrication.[1] Linder considered the Heckscher -Ohlin theorem to be relevant in explaining trade in primary commodities, but saw no such simple explanation of trade in manufactures. He considered "technological superiority, managerial skills, and economies of scale"[2] to be among the most important factors influencing patterns of trade in the latter. Wilkinson, in his analysis of recent Canadian trade patterns, found "that exporting industries, in general, are more physical-capital and human-capital-intensive than are those industries where exports are of minor significance or import competition is substantial."[3] He distinguished between primary and secondary industries with the former accounting for the physical capital-intensity and the latter for the human capital-intensity of Canadian exports.

Hufbauer referred to that class of industries whose location is not dependent on nature's endowments as 'footloose'.[4]

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1 Kravis, "Availability".

2 S. B. Linder, <u>An Essay on Trade and Transformation</u>, (Uppsala: Almquist and Wicksell, 1961), p. 103.

3 Wilkinson, <u>Canada's International Trade</u>, p. 100.

4 G. C. Hufbauer, <u>Synthetic Materials and the Theory of International Trade</u>, (London: Gerald Duckworth and Co. Ltd., 1966), p. 13.

Kindleberger defined footloose industries as those which "have no strong locational pull either to supply or to market."[1] Transport costs are relatively unimportant in footloose industries, while processing costs are quite important. Thus secondary manufacturing industries can generally be considered to be 'footloose'. These industries possess the highest incidence of product differentiation of all sectors of the economy.[2] They are more amenable to differentiation because of the complexities and intricacies of their design and function, as opposed to the more standardized producer-goods and natural resource oriented industries.

It is with respect to these types of industries that the technological gap theory purports to explain trade patterns. An important concomitant of explaining trade flows of the products of the footloose industries is the determination of the location of these industries.

The Technological Gap Theory

The technological gap theory stresses the crucial role in international trade of the country in which a new product or production process is initiated. Both the Ricardian and Heckscher-Ohlin theorems of comparative costs assume constant levels of technology--in the former production techniques differ between countries whereas in the latter they are identical. As early as 1929, J. H. Williams criticized these theories for ignoring, through this assumption, some of the most important factors leading to international trade. In his words,

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C. P. Kindleberger, International Economics, (4th ed.; Homewood, Ill.: Richard D. Irwin, Inc., 1968), p. 99.

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J. S. Bain, Industrial Organization, (New York: John Wiley and Sons, 1959), Ch. 7.

these theories failed to consider in their analysis:

> that the relation of international trade to the development of new resources and productive forces is a more significant part of the explanation of the present status of nation's incomes, prices, well-being, than is the cross-section value analysis of the classical economists, with its assumption of given quantums of productive factors, already existent and employed.[1]

While the Heckscher-Ohlin theorem was extended to include changes in factor supplies and techniques of production, neither type of change in itself was considered more significant in explaining trade than factor endowment ratios. Williams expressed concern that "the economists foreign trade assumptions ignored organic elements of the problem."[2]

Differences in technology were frequently remarked on as a factor contributing to what was considered a dollar shortage in the 1950's,[3] and were again considered relevant when a dollar glut appeared.[4] One of the first economists to seriously suggest a theore-

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J. H. Williams, "The Theory of International Trade Reconsidered," Economic Journal, 39 (June, 1929), p. 196. Although this article appeared prior to the publication of Bertil G. Ohlins, International and Interregional Trade (Cambridge: Harvard University Press, 1933), Williams indicates that he was aware of the theory that was to be advanced from his discussions with Ohlin while the latter was guest lecturing at Harvard.

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Ibid., p. 209.

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See, for example, C. P. Kindleberger, The Dollar Shortage, (New York: Wiley, 1950), Sir Donald MacDougall, The World Dollar Problem (London: MacMillan, 1957), E. Hoffmeyer, Dollar Shortage (Amsterdam: North-Holland, 1958).

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H. B. Lary, Problems of the United States as World Trader and Banker, (New York: National Bureau of Economic Research, 1963), esp. pp. 53-56.

tical approach to international trade with technological superiority being a primary determinant of comparative advantage in manufactured commodities was Kravis in his 'availability' doctrine. Observing that wages in United States export industries were generally higher than the average United States wage level, his investigations led him to conclude "that differences in productivity rather than differences in wages are likely to be the dominant influence in determining the shares of world markets enjoyed by countries producing the same goods."[1] A country imports those commodities which are 'unavailable' at home. Technological progress may confer a temporary monopoly on the innovating industry by reducing production costs, making the commodity 'relatively unavailable' in other countries, or by improving product quality, making the commodity 'absolutely unavailable' in other countries. This temporary monopoly grants the country a competitive advantage in that industry.

Kravis' theorem did not offer the rigor and precision in analyzing and predicting trade patterns as offered by the Heckscher-Ohlin theorem. However, an explanation of trade in such a dynamic context, as will be seen, is perhaps not capable of possessing the same exactitude as was possible under static conditions. The theory has evolved somewhat since Kravis' writing, being stated more explicitly with clarity being added as well as some promising empirical findings regarding its relevance. One of the earlier and most complete

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1 Kravis, "Availability", p. 147.

expositions of the technological gap theory was that of Posner.[1]

The point of Posner's model was to demonstrate that production costs may not be the most important considerations in determining trade flows. He very explicitly confined his discussion of the theory to countries possessing very similar economic conditions. From an equilibrium situation with no trade between two countries, if a product innovation occurs in an industry in one of the countries this innovation will suffice to generate a flow of trade between these countries as the innovating industry will be able to export this new product to the other country. Export of the new product may not commence immediately at its innovation as it may take a while for demand to come into existence for the new product in the other country. The demand lag is not likely to be lengthy, however, in the situation of similar countries postulated here.

Because innovations are assumed to occur in this theory--are indeed the very reason for trade to come about--the comparative advantage achieved by the innovating industry is not necessarily retained permanently. Once the other country is successful in imitating the new product the innovating country will have lost its monopolistic position and, in the absence of further innovations, trade in this product will be determined by cost, and other considerations.

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M. V. Posner, "International Trade and Technical Change," Oxford Economic Papers, New Series, 13 (October, 1961), pp. 323-41.

Attempts to Reconcile the Technological Gap Theory with the Heckscher -Ohlin Theorem

The technological gap theory of trade depends not only on the occurrence of technological change, but also on differences in the rate at which this change occurs within industries and among countries. This involves some very obvious contradictions of part of the underlying framework deemed fundamental to the Heckscher-Ohlin theorem, that techniques of production and characteristics of factors are identical between countries. There is, nevertheless, some controversy as to whether this theory is consistent with, and can in fact be subsumed within, the Heckscher-Ohlin model.

Harry Johnson asserted that the Heckscher-Ohlin model could be quite easily adapted, or 'dynamized', to encompass comparative advantage derived from differences in technology, primarily by redefining the factors of production considered in the model. In his conversion of the Heckscher-Ohlin theorem to a dynamic theory of international economics, labor is considered a homogeneous factor, while

> 'capital' is conceived in the broad sense as comprising natural resources, social capital, human skills, and technical and organizational knowledge, as well as material capital equipment.[1]

Having thus defined his factors, Johnson explained trade on the basis of the relative endowments of these factors.

Johnson, however, appears to be ascribing a more precise explanatory power to his adaptation of the Heckscher-Ohlin theorem than a theorem in such a dynamic context is capable of possessing.

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1 Johnson, Comparative Cost and Commercial Policy Theory, Ch. 11, p. 1.

The Heckscher-Ohlin theorem is geared to inter-industry specialization rather than intra-industry specialization. It is the latter phenomenon which characterizes trade flows in the highly manufactured commodities. The Heckscher-Ohlin theorem, even as propounded by Johnson, is not capable of explaining trade patterns in the situation in which "each country simultaneously produces, exports, and imports products which are very close substitutes for each other in consumption, production, or both."[1]

One could, alternatively, narrow the sense in which productive factors and industries are defined, eliminating intra-industry specialization, and attributing the comparative advantage in each industry, thus defined, again to differences in factor proportions between countries. Such attempts to reconcile the paradox of intra-industry specialization with the Heckscher-Ohlin theorem were anticipated and strongly objected to by Posner.

> The greater the number of 'factors' the more likely it is that any two countries will be unequally endowed with them; thus, as we increase the number of factors, more and more trade is 'explicable.' But, of course, the adequacy of an explanation decreases as it becomes merely a description of what is the case.[2]

Grubel, recognized intra-industry specialization, but went on to incorporate technological change into the Heckscher-Ohlin framework in a manner similar to that of Johnson. He stated that the

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H. G. Grubel, "Intra-Industry Specialization and the Pattern of Trade," Canadian Journal of Economics and Political Science, 33 (August, 1967), p. 374.

2
Posner, "International Trade and Technical Change," p. 327.

types of products in which technological innovations are most likely to occur "may be distinguished on the basis of the research intensity of their development, giving cost-of-production advantages to countries having a relative abundance of human capital,"[1] thus permitting, he claimed, trade in these products to be explained within the Heckscher-Ohlin theorem.

Corden considered all attempts to dynamize the Heckscher-Ohlin theorem to be unsatisfactory, as

> it is not sufficient to refer to differences in research endowments, whether described as capital or specially skilled labor. Two countries may have the same research endowments (measured in terms of cost or the value of the results) and yet trade should still result as they will not discover and develop the same thing at the same time.[2]

Linder, in his discussion of theoretical explanations of trade, would have concurred with Corden's view expressed above. He noted the volatility in trade patterns in manufactured commodities, causing the patterns to be not only unstable but also unpredictable except in a very general sense. He asserted that "the same forces that give rise to trade within each of the countries creats trade between them".[3] He saw some very important trade-creating forces in the elements of monopolistic competition.

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1 Grubel, "Intra-Industry Specialization," p. 374.

2 W. M. Corden, Recent Developments in the Theory of International Trade, p. 32.

3 Linder, Trade and Transformation, p. 102.

Knowledge and Market Structure

A most important characteristic of the world in which we live is that knowledge is increasing continually though not always at a constant rate. In fact, stated Boulding, with matter being subject to the law of conservation and energy to the law of degradation, the only thing that is capable of growing and evolving is knowledge. To follow Boulding a step further, new knowledge is developed through the ability to organize, to create new structures.[1] Innovation in the technological gap theory is the result of new knowledge, the ability to create new structures.

> Technology is society's pool of knowledge regarding the industrial arts. Technological change is the advance of technology, such advance often taking the form of new methods of producing existing products, new designs which enable the production of products with important new characteristics and new techniques of organization and management.[2]

The statement that the source of comparative advantage is some special or unique production knowledge possessed by an industry, or a firm within an industry, in a particular country constitutes a fundamental divergence from perfect competition, one of the necessary attributes of the Heckscher-Ohlin model. Under perfect competition all firms in an industry, and those contemplating entering an industry, have equal access to the body of knowledge required for the production of that industry's product. In a situation where firms

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1 K. E. Boulding, "The Economics of Knowledge and the Knowledge of Economics," American Economic Review, Papers and Proceedings, 1966, pp. 1-13.

2 E. Mansfield, The Economics of Technological Change, (New York: W. W. Norton and Company, Inc., 1968), p. 40.

are able to develop new knowledge for their own exclusive use we have imperfect competition. According to Hesse, international trade theory would more accurately describe current trading patterns

> if it no longer started only from the assumptions of perfect competition, but incorporated in its attempts at explanation heterogeneous competition and also devoted to falling cost curves--which are of course, irreconcilable with perfect competition--more attention than is being given at the present time.[1]

It is the consequent falling long-run cost curves from technological advance that makes precise trade patterns difficult to predict.

Whether the market structure is predominantly characterized by oligopoly or monopolistic competition has not been conclusively determined. With their greater financial strength, which is necessary in undertaking the risks of developing new knowledge, one might suppose that the ability to innovate varies directly with the size of firm, thus producing a tendency towards concentration in these industries. Empirical studies, however, have shown that "in most industries, the productivity of a research and development program of a given scale seems to be lower in the largest firms than in the somewhat smaller firms."[2] Thus one cannot generalize as to

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1 H. Hesse, "The Significance of the Pure Theory of International Trade for Explaining Foreign Trade in the Post-War Period," <u>German Economic Review</u>, 6 (No. 2, 1968), p. 104.

2 J. E. Mansfield, <u>Industrial Research and Technological Innovation</u> (New York: W. W. Norton and Company, Inc., 1968), p. 43. This finding is consistent with those of D. Hamberg, "Size of Firm, Oligopoly, and Research: The Evidence," <u>Canadian Journal of Economics and Political Science</u>, 30 (February, 1964), pp. 62-75, and J. Schmookler, "Market Structure and Technological Change," in <u>Monopoly Power and Economic Performance</u>, ed. by E. Mansfield, (Rev. ed.; New York: W. W. Norton and Company, Inc., 1968) pp. 52-63.

the market structure under consideration except to note that it is imperfectly competitive. Actually, as the product matures the market structure is likely to change.

> Market structures are not static. With the dissemination of know-how and the expiration of patents a market structure typically evolves from monopoly to oligopoly, and perhaps eventually to monopolistic competition.[1]

Advance in technology by a firm is not a spontaneous occurrence, but rather is the culmination of considerable expense and effort—technological advance comes from within the system rather than from without. In spite of the risks involved in any specific research and development project, the firm may be forced to keep abreast of technological advances if it is to survive in a growing economy and more so if it is to maintain its share of the market. Potential profits provide an even greater incentive to innovate. Technological advance may provide its own accelerator as it puts a squeeze on the dormant firm. As wages rise due to general economic growth the firm's costs of production increase and the successful imitation, and perhaps eclipse, of an advance in technology by competing firms reduces the return to firm's innovation.

Apart from this imperative to innovate there is a further incentive to innovate provided by the fact that the demand for products of the industries considered here is highly income elastic. As incomes and standards of living steadily increase the demand for

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1 Hufbauer, Synthetic Materials, p. 43.

superior and more sophisticated products increases more than proportionately, thus inducing efforts to innovate.[1]

Diffusion of New Knowledge and the Product Cycle

A new product or technique is most likely to originate in the country in which it is to be marketed. It will be produced initially for the domestic market because this is the market in which the producer is most familiar with demand conditions. Because of the income elasticity of demand for highly fabricated commodities, the country in which the innovation occurs will be one of high incomes. A further reason for the product to originate from a high income country is the high human and physical capital requirements in the early stages of product development. While physical capital may be quite mobile, human capital is available only in high income countries. In its early stages the product will enjoy a monopolistic position so production costs will be a less important factor.

Competitors in this industry in the country of origin of the innovation and in other countries to which the product is being exported will attempt to imitate the new product so they can share in the monopolistic profit acruing to it, or at least so they can

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1 K. J. Lancaster, "Change and Innovation in the Technology of Consumption," American Economic Review. Papers and Proceedings, 56 (May, 1966), pp. 14-23. The whole process of technological change can be viewed from the position of the consumer by considering products as means which possess the characteristics that satisfy consumers' wants. New products simply possess these want-satisfying characteristics in new proportions. A new product will constitute a technological advance if it permits the consumer's efficiency frontier, in terms of characteristics, to move outward. As effective demand increases there will be incentive to create new products.

maintain their share of the market. Imitation by competitors means they must also engage in the risky venture of investing to acquire the new technological knowledge required for the new product. Mansfield devised a simple model which so far has stood up very well in empirical testing for forecasting the intensity of imitation. He hypothesized that the probability of a firm introducing a new technique is an increasing function of the number of firms already employing the technique and the profitability of doing so, and a decreasing function of the size of the required investment.[1]

As diffusion of the innovation occurs, trade in this commodity will decrease. Trade will not likely cease completely, however, even when diffusion is fairly widespread as there are likely to be some different characteristics in the products of each firm making them slightly unique.[2] Trade flows between some countries may be reduced before the innovation has been successfully imitated as the innovating firm may establish a subsidiary or affiliate plant in foreign markets when it sees imitation is imminent in order to protect its market in that country, or alternatively, it may invest abroad in order to penetrate highly protected markets.

As the innovation becomes more widely diffused competition in the industry increases, and as competition increases costs of

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1 Mansfield, <u>The Economics of Technical Change</u>, p. 120.

2 It must be remembered that product differences can be created in the minds of consumers as well as being based on real qualitative differences.

production become a more important consideration to the producers. After being marketed for a certain time the product becomes quite standardized, no longer requires the specialized services available only in the high income countries, and is then amenable to mass production techniques. In the early stages of the development of the product the high wage rates do not represent a cost disadvantage. Once the product has become standardized and the innovating firm has lost its temporary monopolistic position, the possibility of lowering production costs by transferring production to economies where wage rates are lower becomes very attractive. This transfer of production facilities is likely to be undertaken by the producers in the high income countries through international investment.[1]

Thus as the product matures, production facilities will be transferred to a less developed country to take advantage of the lower labor cost, so the country which originally gained its competitive advantage by introducing the new product to the market will now be importing this product as it can be obtained from abroad for a much lower price than it can be produced at home. This tendency for trade flows to reverse themselves is frequently attached to the technological gap theory as its natural sequal and is referred to as the product-cycle theory. The important element is that the methods of production as a product matures follow a sequential pattern--the actual number of stages distinguished may vary somewhat.[2] In the

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R. Vernon, "International Investment and International Trade in the Product Cycle," Quarterly Journal of Economics, 80 (May, 1966), pp. 190-207.

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Compare the stages distinguished by Vernon, ibid., with those of Hufbauer, Synthetic Materials.

early stages a product requires, apart from marketing considerations, large amounts of highly skilled manpower to produce the advance in technology as well as other highly specialized external economies available only in highly developed countries. As Mikesell states, with respect to the United States,

> when a new product or production method is being developed, or a new market exploited, costs are less important because of uncertainties, large development outlays, and the absence of competition. However, once products have been standardized for a mass market in the United States and for export, cost factors become far more important to entrepreneurs than during the early stages of product and market development.[1]

Some Empirical Investigations Regarding the Technological Gap Theory

While I do not pretend to be making a comprehensive survey of all empirical studies relating to the technological gap and product cycle theories, I would like to consider several which lend some of the problems inherent in such undertakings and providing a useful background and introduction to the type of empirical analysis to be ventured in the following chapters.

Hufbauer made one of the most ambitious attempts to explain trade patterns in manufactured commodities.[2] He considered three types of theoretical approaches which have been developed to explain trade

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1 R. F. Mikesell, "Decisive Factors in the Flow of American Direct Investment to Europe," Economia Internazionale, 20 (Agosto, 1967), pp. 446-47.

2 Hufbauer, Synthetic Materials.

patterns--the factor proportions account, the scale economy account, and the technological gap account--and examined their validity with respect to trade patterns in synthetic materials, a representative footloose manufacturing industry. His findings led him to reject the factor proportions account as being not relevant in explaining trade in footloose manufactures. Its inapplicability stems largely from the restrictive nature of the assumptions which necessarily underlie the theory, especially the assumptions of identical technology between countries and constant returns to scale. Hufbauer sought to explain a country's exports as a percentage of world exports on the basis of four independent variables: imitation lags, wage levels, size of domestic markets, and accumulated volume of past production. His regression equations yielded coefficients of determination of approximately .9,[1] however the multicollinearity between domestic market sizes and imitation lags prevented Hufbauer from separately distinguishing the effects of economies of scale and the technological gap as determinants of international trade. While his statistical analysis did not reveal which of the two theories is superior in terms of explaining trade, insofar as policy implications are concerned Hufbauer suggests the latter is potentially of greater importance.

> The technological gap theory does not, however, depend upon artificial trade barriers. One may therefore speculate that a free trade world would witness an expanded role for technological gap trade as opposed to scale economy trade.[2]

1
Ibid., Appendix C.

2
Ibid., p. 112.

Hufbauer strongly emphasized throughout his book that when considering international trade in a dynamic setting a product cycle occurs which may change the direction of trade flows as the commodity ages. However, he presented the interesting empirical result that not only do new products originate from the more highly developed countries, but these products constitute the bulk of all goods traded.[1] Thus trade in the initial stages of the existence of a commodity, technological gap trade, is more important than that which occurs in the latter stages.

Keesing admitted in his initial article that the treatment of trade patterns as being determined by the availability of skilled and unskilled labor in a Heckscher-Ohlin fashion may be somewhat superficial.

> Attributing an advantage in location to skills also ignores leads and lags in technology. Some of the influence on trade here attributed to skills could alternatively be credited to the technological advantages that are so closely connected with skills.[2]

In a more recent article Keesing elaborates more fully on this statement and attempts to test the hypothesis that the competitive strength of United States manufacturing industries in world markets is due to their ability to produce new products.[3] The amount of research

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1 *Ibid.*, Diagram 6-9, p. 107.

2 Keesing, "Labor Skills and International Trade," p. 290.

3 D. B. Keesing, "The Impact of Research and Development on United States Trade," *Journal of Political Economy*, 75 (February, 1967), pp. 38-48.

and development (R & D) carried on by an industry is taken as the indicator of the rate of innovation of new products by that industry. Correlating the scientists and engineers engaged in R & D as a percentage of each industry's total employment with United States exports as a percentage of the total exports of that industry for ten leading industrial nations, Keesing obtained a linear correlation coefficient of .88 and a Spearman rank correlation coefficient of .94. Using R & D expenditures as a percentage of value added for each industry as indicator of R & D activity, he got a linear correlation of .66 and a Spearman rank correlation of .78. He finds some strong systematic relationships between scientists and engineers engaged in R & D and other skill categories, however the association between scientists and engineers in R & D and competitive trade strength is considerably stronger than that for any other skill category. He also found that industries involved in an intensive R & D effort are frequently characterized by greater than normal economies of scale.

Using an approach similar to that of Keesing, Gruber, Mehta, and Vernon also attempted to determine the influence of R & D on international trade.[1] They considered two indicators of R & D effort

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1 W. Gruber D. Mehta, and R. Vernon, "The R. D. Factor in International Trade and International Investment of United States Industries," Journal of Political Economy, 75 (February, 1967), pp. 20-37.

for each industry: total R & D expenditures as a percentage of sales, and scientists and engineers in R & D as a percentage of total employment. Also, they considered two indicators of the export strength of each industry: exports as a percentage of the total sales of the industry, and the excess of exports over imports as a percentage of the total sales of the industry. Correlating these indicators of R &D effort and export performance, they get linear and Spearman rank correlation coefficients ranging from .69 to .79, all significant at the .01 level.

Gruber, Mehta, and Vernon also found that the industries most actively engaged in R & D activity are also those which most frequently invested in production facilities abroad. They see the decision concerning international investment as involving a number of variables, rather than simply the rationale of lower labor costs usually associated with the product cycle theory. Technically advanced products may require marketing agencies abroad to enable the domestic producer to gear his product for that market as well as to educate the foreign consumers. Once a marketing organization has been set up abroad, the marginal costs of establishing production facilities may be sufficiently reduced to make that economically feasible as well. Alternatively, the decision to invest abroad may be motivated by the oligopolistic rule of thumb of maintaining market shares, here world markets. Whatever the reasons, international investment is seen as an effective and important means of maintaining contact with foreign markets.

Kaliski criticized the conclusions derived from the high association found between R & D activity and export performance in United

States manufacturing industries found by Keesing and Gruber, Mehta, and Vernon on the basis that they ignored the extremely important role played by the United States government in promoting R & D. With the large extent to which R & D is government financed, Kaliski asserts "that one cannot tell whether the superior export performance of R & D-intensive American industries is a reflection of comparative advantage or of an export subsidy."[1] Mansfield found that when company-financed R & D alone is considered, while the differences in total R & D activity among industries is reduced, the rank ordering remains very much the same.[2] According to Mansfield the amount of resources the government will devote to R & D in a particular industry depends on the relation of that industry to defence, public health, or other areas where government assumes the responsibility, on the potential external economies to be generated by this R & D, and on other purely political factors.[3] While the government does subsidize R & D quite highly, that comparative advantages is a result of the R & D rather than the subsidies is supported by the other studies reviewed in this section which use very diverse approaches.

The empirical work of Shen is relevant both to the technological gap theory and the product cycle theory.[4] Defining competitive advantage to be the monopolistic or monopsonistic power enabling a

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1 S. F. Kaliski, "The R & D Factor in United States Trade--A Comment," Journal of Political Economy, 75 (October, 1967), pp. 761-2.

2 Mansfield, The Economics of Technological Change, p. 59.

3 Ibid., p. 17.

4 T. Y. Shen, "Competition, Technology, and Market Shares," Review of Economics and Statistics, 50 (February, 1968) pp. 96-102.

plant to increase its market share, he considered some of the causes of, and the duration of, this power. Correlating the growth rates of four thousand selected manufacturing plants over two successive time intervals, he finds his correlation coefficients to be generally negative. While coefficient values in correlating successive annual growth rates are low, the coefficients increase in absolute size, as the interval is extended. These negative correlations reflected the fact that the factors responsible for the high growth rate during the initial interval were not present during the second, making competitive advantage impermanent. "The factors contributing to a persistent but impermanent competitive advantage fall into three groups: product differentiation, price advantages, and productivity advantages."[1] Also, dividing the plants into five technology classes ranging from 'very advanced' to 'very backward', he found that between 1935 and 1959 technological mobility--between classes--was very great with the initial competitive advantage of firms largely dissipated within a decade.

Hirsch's empirical analysis of trade in the electronics industry emphasized the cycle aspect of the theory, his postulate being that the more developed the economy the greater the comparative advantage it will possess in growth products and the lesser comparative advantage in mature products.[2] He distinguished six sectors in the United States electronics industry, compared the exports of the various sec-

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1 Ibid., p. 99.

2 Seev Hirsch, Location of Industry and International Competitiveness, (London: Oxford University Press, 1967).

tors with competing imports, and examined the trade balance of each sector over a period of time. Gauging the maturity of the sectors by the relative changes in value added over the fifteen year period 1947-62, he found two distinct groups of sectors in terms of trade balances improving and deteriorating. The sectors with improving trade balances were those in which rapid growth of value added had occurred. Thus he concluded there was a negative correlation between the maturity of the sectors of the United States electronics industry and their international trade performance.

Having looked at the theory and some empirical investigations regarding new technology and international trade, it may be valuable to regress slightly and reflect on some of the empirical studies considered in the previous chapter. The product cycle and the information provided by Hirsch as to characteristics of industries at different stages of the cycle help explain Leontief's empirical findings which were considered paradoxical in light of the Heckscher-Ohlin theorem. Products in the first phases of the product cycle are labor and skill intensive, while mature products are capital intensive. The United States possesses a strong demand for new products because of its size and affluence, and also because of its large military and space programs. New products are thus highly likely to originate in the United States so, as country of origin, it will possess a comparative advantage in them. Leontief's finding that the United States exports labor intensive commodities, especially those utilizing skilled labor intensively, is not surprising as Hirsch's empirical investigations revealed the existence of "a high degree of correlation

between the measures which were used to indicate growth, labor and skill intensity, and international competitiveness."[1]

While new technology and the product cycle do cast some further light on the results of Keesing's first two articles,[2] they also raise some questions as to his techniques. The reason the United States—especially the United States, but also to some extent the other highly industrialized countries—exports commodities which are skilled labor intensive is because of the comparative advantage it possesses in the production of new products which are skill intensive. The product cycle, however, clearly contradicts Keesing's assumptiom that the combination of skill requirements observed in an industry in the United States is applicable to that industry in all other countries. In fact, the product cycle theory would suggest that Keesing's technique of applying United States skill coefficients to the trade of all other countries should not provide any meaningful results at all. Provided the industries used in such a study are at a sufficiently aggregative level to include both new and mature products, using only one set of skill coefficients would mean the less developed countries could be producing and exporting the mature products of an industry with the same skill combinations as used in

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1 <u>Ibid</u>., p. 82.

2 Keesing, "Labor Skills and International Trade," and "Labor Skills and Comparative Advantage."

the United States to produce new products. The greater scope for introducing new products in some industries than others, thus creating basic differences in skill structures between industries, combined with Hufbauer's finding that the exports of first-phase products constitute the bulk of world exports explains why Keesing's results do reveal some definite patterns.

Chapter Three

NEW TECHNOLOGY AND CANADA'S EXPORTS

Having looked at the work done by Keesing in relating labor skills and international trade, and also the work by Keesing and others in attempting to provide some empirical support for the technological gap theory of trade, I would like now to consider the relevance of the technological gap theory in explaining some recent Canadian trade flows in secondary manufactures. The hypothesis which underlies this empirical work is that the degree of importance the technological gap plays in determining the trade patterns of the nation, and the stage of the product cycle at which the nation in general is producing, is manifested through the utilization of labor skills within the country.

> A high degree of labour-intensity characterizes the manufacturing process...The composition of the labor force is especially significant. Scientists, engineers, and skilled laborers assume a role of crucial importance, since their professional skills are required to cope with the many problems of design and engineering which inevitably accompany the introduction of new products.[1]

According to the technological gap theory, those industries which are internationally competitive are the ones making innovations in the product and in the production process. The innovating industries employ skilled labor intensively, much of which is not involved directly in the production process but rather is occupied exclusively in attempting to produce ameliorations in products and processes through research and development.

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1 Hirsch, Location of Industry and International Competitiveness p. 83.

A test of this hypothesis requires definitions of labor skills, international competitiveness, and industries, as well as the choice of statistical techniques to be used in relating the variables. The approach used here resembles in many respects that used by Keesing in correlating the labor skill utilization with international trade competitiveness for United States industries,[1] thus accounting for the considerable amount of attention devoted above to his work.

Labor Skills

In order to gauge the impact of the composition of the labor force on the international competitiveness of an industry, one must categorize the labor force by skill levels. The categorization adopted here is intended to parallel that used by Keesing.[2] His breakdown of the labor force is particularly concentrated in the more highly skilled categories, which are those most closely involved in innovation. Thus, the eight major skill categories into which the labor force is divided are:

1. Scientists and engineers
2. Technicians and draftsmen
3. Other professionals
4. Managers
5. Machinists, electricians and tool and die makers
6. Other skilled manual workers
7. Clerical and sales workers
8. Unskilled and semi-skilled workers

These categories are comprehensive of the entire labor force,

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1 Keesing, "Labor Skills and Comparative Advantage," Table 3, p. 256.

2 *Ibid.*, p. 254.

the specific occupations included in each category being given in Appendix A. The complete occupational classification, on which my categorization is based and within which employment data by labor skills is published for Canada, is that of the Occupational Classification Manual, Census of Canada, 1961.[1] The results, using these skill categories, may not be precisely comparable to those obtained by Keesing for the United States as I cannot be sure that the categories used here correspond exactly to those used by Keesing because he did not include his definitions of skill categories with his published article. While with most occupations it is quite clear to which category they belong, some required a bit of arbitrary judgement on my part.[2] This difficulty in assigning occupations to the major skill categories, however, was primarily with respect to semi-skilled and skilled manual workers and not the more highly skilled categories which are most relevant to this study. Even if Keesing had delineated his skill categories very specifically it is not certain that the Canadian occupations could have been translated precisely into this framework as the occupational classification used in the United States Census differs somewhat from that used in the Canadian Census.

Upon defining the skill categories, skill coefficients are then

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1 Dominion Bureau of Statistics, Occupational Classification Manual, Census of Canada, 1961, (Ottawa: Queen's Printer).

2 I consulted with Dr. C. Steinberg, labor economist, formerly of the University of Alberta, in regards to my categorization of occupations.

derived for each industry by calculating the percentage of total employment in each skill category for that industry. The most recent employment figures of this nature available for Canada are those of the 1961 Canadian Census.[1]

While the eight skill categories above do encompass the entire labor force, I have in some cases subdivided these categories further in hopes of casting some additional light on the underlying reasons for the international competitiveness of Canadian manufacturing industries. Most of this additional breakdown has been in the professional categories. The specific partial categories which have been further considered are:

1. Managers (wage-earning)
2. Clerical workers
3. Laborers
4. Statisticians, economists, and programmers
5. Auditors and accountants
6. Engineers
7. Scientists

In addition to considering the relevance of the labor skills employed by a particular industry in determining its international competitiveness, I have also considered some alternative indicators which perhaps reflect more directly the changing technology from which an industry derives its export strength. Two measures of the research and development activity within an industry, one reflecting the skilled labor involved in R & D and the other expenditures on

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1 Canada, Dominion Bureau of Statistics, Census of Canada, 1961 Vol. 111, part 2, Detailed Occupations by Industry Groups and Sex (Ottawa: Queen's Printer).

R & D have been used:

8. Professional personnel engaged in R & D as a percentage of the industry's total employment
9. Expenditures on R & D as a percentage of the value of the industry's sales.

International Competitiveness

Conventional trade theory asserts that price differences among countries are the cause of international trade. Thus in determining which country held the comparative advantage in a commodity, one ought to compare prices of this commodity among the various countries. There are some difficulties involved in this type of analysis. International trade leads to a reduction--or elimination under the rigorous assumptions of the Heckscher-Ohlin theorem--of price differences, so the pre-trade price ratios which caused trade in the first place would no longer exist. Barriers to trade exist, so if price differences could be unearthed one would still have to account for transport costs between countries and tariffs and quotas imposed by each country on each commodity. Also there are the statistical problems of obtaining prices from the various countries, and weighting and indexing the various currencies.[1] These problems, however, are perhaps not as important in testing the technological gap theory as it is primarily concerned with non-price determinants of trade patterns. How can prices of commodities be compared when the very basis of trade is that commodities are exported because other countries do not possess the productive knowledge to produce them?

Balassa suggested that rather than engaging in the laborious

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1 Hesse, "The Significance of the Pure Theory," pp. 93-94.

exercise of attempting to consider all factors determining comparative advantage, one simply look at 'revealed' comparative advantage.[1] Comparative advantage can be revealed through relative export performances, or export-import ratios for each country. As the latter are especially vulnerable to distortion from differences in consumer tastes and tariff structures among countries, Balassa considers export performance to be the best indicator of comparative advantage. This is also the type of indicator used by Keesing.[2]

Export performance is the indicator of the international competitiveness of an industry with which labor skills are to be related here. Export performance measures the share of world markets possessed by an industry. Canadian exports for each industry are normalized by dividing them by the total exports of that industry of the leading industrial nations, so Canada's market share is its exports as a percentage of world exports in that industry. The leading industrial nations are thosereferred to by Keesing as the Group of Ten, and include the United States, United Kingdom, Federal Republic of Germany, France, Italy, Belgium, Netherlnds, Sweden, Canada, and Japan.[3] These countries account for over four-fifths of total world

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1 Bela Balassa, Trade Liberalization Among the Industrial Countries: Objectives and Alternatives, (New York: McGraw-Hill Book Company, 1967), Chapter Four, Appendix B.

2 Keesing, "Labor Skills and Comparative Advantage," and "The Impact of Research and Development on United States Trade."

3 Keesing, "The Impact of Research and Development," p. 38.

exports of manufacturing industries.[1]

The use of 1961 skill data and exports data implies that there exists a one year lag between the employment of specific labor skills and the manifestation on the export market of their contribution to the industry's competitiveness. Mansfield, in attempting to ascertain the duration of the lag from invention to innovation, found that while there was a great deal of variance, it could be said that

> the lag has been decreasing over time, that it is much shorter for consumer products than industrial products and that it is much shorter for innovations developed with government funds than for those developed with private funds.[2]

While the lags estimated by Mansfield are considerably longer than one year, the inventions considered are of a much more fundamental nature than those which presently characterize the manufacturing industries. Keesing found that his correlations were not greatly effected by the years chosen as the structure of R & D activity by industry and patterns of export performance have been relatively stable in recent years in the United States.[3]

Industries

Some concept of industry must be adopted for relting the data with respect to labor skills to that for export performance. The

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1 Balassa, Trade Liberalization, p. 204.

2 Mansfield, The Economics of Technological Change, p. 102.

3 Keesing, "The Impact of Research and Development," footnote 8.

definition adopted here in using Canadian data is the major industry groups of that manufacturing sector: that is, industries are distinguished at the two-digit level of the Canadian Standard Industrial Classification (S. I. C.).[1] In the manufacturing sector of the Canadian S. I. C. there are twenty major industry groups:

1. Food and beverage
2. Tobacco products
3. Rubber
4. Leather
5. Textiles
6. Knitting mills
7. Clothing
8. Wood
9. Furniture and fixtures
10. Paper and allied
11. Printing, publishing, and allied
12. Primary metal
13. Metal fabricating
14. Machinery (except electrical)
15. Transportation equipment
16. Electrical products
17. Non-Metallic minerals
18. Petroleum and coals
19. Chemicals and chemical products
20. Miscellaneous manufacturing

A further distinction within these twenty industries was made between primary and secondary manufacturing industries. The Dominion Bureau of Statistics defines a primary manufacturing industry as one in which at least fifty percent of the total value of material inputs are from the primary sector of the economy.[2] Four industries--major industry groups 1, 8, 10, and 18--were

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1 Canada, Dominion Bureau of Statistics, Standard Industrial Classification Manual, (Ottawa: Queen's Printer, 1960).

2 Unpublished DES paper, "Primary and Secondary Manufacturing in Canada," cited in Wilkinson, Canada's International Trade, p. 94.

clearly primary manufacturing industries, while there is some doubt as to whether Primary metals is a primary or secondary manufacturing industry. In terms of its skill structure, however, it appears most reasonable to consider it as a primary manufacturing industry.[1]

The two-digit industries are highly aggregative as is evident from the enumeration of them given above. A further subdivision of these industries, say to the three-digit level, would likely have been more revealing in some respects, as the disparities between industries would become more prominent as the industries considered become more homogeneous entities. Unfortunately, complete data are not available to permit analysis at the three-digit level. While there may be some short-comings in using the two-digit industries, some heterogeneity in the industries considered is necessary as the technological gap theory is more concerned with intra-industry specialization than inter-industry specialization.

It is important that, whatever level of aggregation one chooses to work with in regards to industries, this level is used consistently. The distinction of industries according to the S. I. C. may very well possess many deficiencies, and may in many cases appear to be somewhat arbitrary. However, to consider industries at different levels of aggregation would cause one's work to be extremely vulnerable to the criticism that the industries had been deliberately

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1 The correlations in Tables 1 and 2 below were initially calculated with Primary metals considered as a secondary manufacturing industry and as a primary manufacturing industry. Only the latter, however, are given below.

chosen to achieve the desired correlations. In spite of the shortcomings the S. I. C. may possess, attempting to distinguish industries by any other criterion would be beyond the scope of this paper. Yet, any arbitrary grouping of industries, other than that in the S. I. C., could not be justified.

Unfortunately, not all the work done in this area has followed this rule. Keesing, in his article in which he considers forty-six industries,[1] appears to have been rather arbitrary and perhaps inconsistent in his choice of industries. Some of the industries used by him are two-digit industries in the Canadian S. I. C., while some of them are not distinguished even at the four-digit level.[2] Thus Keesing's results, which appear to be highly significant, may be partially due to his choice of industries as well as the inherent structural differences that exist between industries.[3]

Again, in looking at R & D directly rather than at labor skills, Keesing covered only a portion of the manufacturing sector, and the

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1 Keesing, "Labor Skills and Comparative Advantage," Keesing does not reveal in this article the industries used, however, I was able to obtain this information from B. W. Wilkinson.

2 While there are some slight differences between the Canadian S. I. C. and the United States S. I. C., which Keesing uses, the rationale for his choice does not appear any more obvious when considered in terms of the United States S. I. C.

3 In correlating Keesing's skill coefficients with Canadian export data I got no statistically significant correlations for the forty-six industries and only one statistically significant correlation--the rank correlation for other skilled manual workers--in considering only the thirty-five footloose manufacturing industries.

industries he chose were not all at the same level of aggregation.[1] Gruber, Mehta, and Vernon are more consistent in their choice of industries than Keesing was, however they disaggregated three of the two-digit industries without offering any rationalization.[2] The correlation coefficients obtained by Gruber, Mehta, and Vernon are, incidentally, lower than those obtained by Keesing, however, as they use different indicators of export performance one cannot say whether the differences in correlation coefficients are due to their differing choice of industries.

Determining the value of exports for Canadian industries and the Group of Ten industries required some further conversions of classifications as export data was obtained from the United Nations Commodity Trade Statistics,[3] where exports are classified according to the Standard International Trade Classification (S. I. T. C.). The S. I. T. C. categories which correspond to the twenty two-digit manufacturing industries of the Canadian S. I. C. are given in Appendix B.

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1 Keesing, "The Impact of Research and Development."

2 Gruber, Mehta, and Vernon, "The R & D Factor in International Trade."

3 United Nations, Commodity Trade Statistics, 1962, Statistical Papers, Series D, Volume XII (New York: United Nations, 1963).

Chapter Four

THE EMPIRICAL RESULTS

"Innovation does not simply come from outside the economic system --it is created within it."[1] Technological progress is not something that occurs spontaneously or accidentally, but is rather the culmination of a very conscious effort. This effort takes the form of research and development activity. The firm that is successful in innovating is very science and technology oriented, interested in extending the bounds of knowledge and, more importantly, in applying new knowledge produced by its own research staff, or acquired from other sources, to its own product or production process. In a competitive industry it is only those firms which are constantly innovating, and thereby improving the product or process, which are able to maintain a competitive advantage, and in the long-run remain economically viable. Similarly between countries, if a particular industry is characterized by innovation to a greater extent in one country than in another, the country able to introduce superior products or techniques of production will possess the comparative advantage in that industry.

Whether the technological gap theory, which is briefly recapitulated in the preceding paragraph, can be advanced as a relevant explanation of Canada's exports in manufactures must now be examined. Linear correlation coefficients and Spearman coefficients of rank correlation between the exports and skill requirements of Canada's manufacturing industries have been derived from the data discussed in the preceding chapter. These correlations are presented in Tables

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1 B. R. Williams, Technology, Investment and Growth, (London: Chapman and Hall Ltd., 1967), p. 35.

TABLE 1

CORRELATIONS BETWEEN THE PERCENTAGE OF THE LABOR FORCE BELONGING TO EACH SKILL CLASS AND THE INDUSTRY'S EXPORT COMPETITIVE POWER FOR CANADA.[a]

		All Manufacturing Industries[b] Rank Correlation	All Manufacturing Industries Linear Correlation	Secondary Manufacturing Industries[c] Rank Correlation	Secondary Manufacturing Industries Linear Correlation
.	Scientists and Engineers	.0632	-.1182	.6400*	.6533*
1.	Technicians and Draftsmen	.1684	-.1076	.4839	.5495*
11.	Other Professionals	-.0797	-.2073	.0982	.1653
V.	Managers	-.0241	-.1645	.3107	.2688
.	Machinists, Electricians and Tool and Die Makers	.2271	-.0910	.2893	.3103
71.	Other Skilled Manual Workers	.1617	.4284*	.2572	.1343
711.	Clerical and Sales Workers	-.0474	.3549	.4286	.5168*
7111.	Unskilled and Semi-skilled Workers	-.2421	-.0245	-.4786	-.4945*

*Statistically significant at .05 level.

a. Skill data obtained from Canada, Dominion Bureau of Statistics, Census of Canada, 1961, Vol.111, part 2, Detailed Occupations by Industry Groups and Sex, (Ottawa: Queen's Printer, 1963), and export data obtained from United Nations, Commodity Trade Statistics, 1962, Statistical Papers, Series D, Vol. X11, (New York: United Nations, 1963).

b. Includes all twenty major industry groups in the manufacturing industry.

c. Major industry groups 1, 8, 10, 12, and 18 of the manufacturing industry deleted.

TABLE 2

CORRELATIONS BETWEEN SOME SKILL CATEGORIES PLUS INDICATORS OF R & D AND INDUSTRY'S EXPORT COMPETITIVE POWER FOR CANADA[a]

	All Manufacturing Industries[b]		Secondary Manufacturing Industries[c]	
	Rank Correlation	Linear Correlation	Rank Correlation	Linear Correlation
. Managers(wage-earning)	-.0662	-.2591	.4143	.4661*
. Clerical Workers	.0406	-.3088	.4643	.5093*
. Laborers	.3038	.7769*	-.3036	-.1843
.. Statisticians, Economists and Programmers	.1939	-.0637	.4286	.6190*
i. Auditors and Accountants	.1759	-.0220	.4679	.4837*
). Engineers	-.0147	-.1226	.6400	.5655*
'. Scientists	-.1049	-.0851	.3810	.5518*
3. Professional Personnel in R & D	-.0857	-.2658	.4909	.6719*
). R & D Expenditures as percentage of sales	-.2036	-.4498*	.6364*	.4346

Statistically significant at .05 level.

a. Data sources same as in Table 1, plus data for R & D indicators obtained from Canada, Dominion Bureau of Statistics, Industrial Research and Development Expenditures in Canada, 1961, (Ottawa: Queen's Printer, 1963), Tables 8 and 10.

b. Includes all twenty major industry groups in the manufacturing industry.

c. Major industry groups 1, 8, 10, 12, and 18 of the manufacturing industry deleted.

1 and 2, the correlation coefficients for the eight skill categories which are comprehensive or the entire labor force being in Table 1, and the correlation coefficients for the seven sub-categories of labor skills plus the two additional indicators of R & D activity being given in Table 2.

As already postulated at the beginning of Chapter Three, the employment of skilled manpower is crucial to the process of innovation as new technology is generated by special skills and talents in the labor force. The skill intensity of an industry is indicative of the orientation of that industry towards new technology. Thus in attempting to ascertain the importance of new technology in Canada's export of manufactures, the contribution of the categories of labor skills outlined above to international competitiveness will be considered.

The technological gap theory appears immediately to have some validity and relevance with respect to Canadian trade in secondary manufactures as the employment of workers in the most highly skilled categories is positively associated with competitive trade power in these industries. For scientists and engineers, the first skill category, both the Spearman coefficient of rank correlation and the linear correlation coefficient are positive and statistically significant, at .6400 and .6533, respectively, for Canada's exports of secondary manufactures. This skill category is expected to have the highest correlations as scientists and engineers are, of all the skill categories considered here, the most actively and vitally involved in research and development; they are pre-eminently responsible for "the creation of an idea and its reduction to practise."[1]

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J. A. Allen, Scientific Innovation and Industrial Prosperity, (Amsterdam: Elsier Publishing Co., 1967), p. 8.

It should also be noted that the correlation coefficients of scientists and engineers corroborate the previously stated expectation that the technological gap theory is applicable only to highly fabricated commodities, and not to those commodities strongly oriented towards natural resources. The strong positive correlations between the employment of scientists and engineers and the industry's export performance referred to above exist only for the fifteen secondary manufacturing industries. When considering all twenty industries of the Canadian manufacturing sector there are no meaningful associations; both coefficients differ only marginally from zero, the rank correlation being .0632 and the linear correlation --.1182. Keesing, in correlating scientists and engineers engaged in R & D as a percentage of the industry's total employment with that industry's exports as a percentage of the exports of the Group of Ten, found that in omitting five of the eighteen industries because of their strong natural resource orientation his correlation coefficients stayed very much the same.[1] From this he concluded that "the basic association cannot be attributed to the effects of natural resource shortages."[2] In both Canada and the United States the natural resource oriented industries are among least actively engaged in R & D. Being relatively much more natural resource abundant than the United States, Canada is a stronger exporter of natural resource

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1 Keesing, "The Impact of Research and Development," p. 42.

2 *Ibid.*

oriented commodities while the United States accounts for a very small proportion of the exports of these commodities. The relation between R & D and export performance held for Keesing when he included the natural resource oriented industries owing to the relative shortage of natural resources in the United States which weakens the export strength of these industries. The lack of a relation between the exports of primary manufacturing industries and new technology is seen more clearly in viewing the Canadian economy where natural resources are so much more abundant, as the basic association disappears when the primary manufacturing industries are included.

It has been suggested that the contribution of scientists and engineers, respectively, to the creation of new products and processes differs slightly.[1] The former are engaged in the study of "the fundamental natural sciences" while the study of the latter is somewhat less pure, being primarily concerned with the application of science to industry. Dissecting the scientists and engineers category to consider the contribution of each separately, three of the four new correlation coefficients obtained for the secondary manufacturing industries are lower than either of the original coefficients for the combined group, while the rank correlation for engineers just equals that for scientists and engineers. While the strength of the correlations diminishes slightly on making the dichotomy, it would appear that engineers, the more practically oriented of the two make a slightly more substantial contribution to export

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[1] C. F. Carter and B. R. Williams, Industry and Technical Progress (London: Oxford University Press, 1957), p. 15.

strength than do scientists, as the coefficients for engineers are slightly higher than those for scientists, the rank correlation for the latter not even being statistically significant.

Again, when considering scientists and engineers separately, that association disappears when the primary manufacturing industries are included as well. Here, in fact, all of the coefficients when considering all twenty manufacturing industries are negative. That the signs of the coefficients can be reversed by the inclusion of the five primary manufacturing industries is due to the fact that many smaller industries--such as tobacco, leather, knitting, clothing --do not employ scientists and/or engineers, once again coupled with the fact that the primary manufacturing industries are simultaneously the strongest exporters and less active in R & D.

While scientists and engineers, the most highly skilled category, has, as expected, the highest correlation with exports of secondary manufactures, it would be incorrect to expect this correlation to be perfect as not all new products or new processes introduced in a firm, or an industry, are the sole or direct result of the scientists and engineers employed by it. The research may occur in universities or be undertaken by research associations, private or public, or licenses or special knowledge may be acquired from other firms or affiliates in other countries. Freeman found in the chemical industry that while most of the major innovations came originally from within the chemical industry, minor innovations and productivity increases were frequently the result of the work of contractors, rather than employees of the firm, who specialized in the design, engineering, and construction of process plants for the

oil and chemical industries.[1] Apart from the fact that innovations may sometimes be acquired from other sources, there is a great deal of uncertainty and risk involved in R & D and innovation so one cannot guarantee that engagement in R & D will ensure success in the product market for a firm. Mansfield cites the estimate, which fails to mention the number of projects considered for R & D, that five of every ten products emerging from R & D, fail in product and market tests, and only two of the five passing these tests become commercially successful.[2] Thus, in view of the riskiness of innovation, the acquisition of innovations from external sources, and other factors which may diminish the role of the firm and its employees in determining the rate of innovation, the above results must be considered very satisfactory.

The second skill category, technicians and draftsmen, is also positively correlated with export performance, although the coefficients are lower than those of scientists and engineers. The rank correlation coefficient is .4839, while the linear correlation coefficient is, .5495, only the latter being statistically significant at the .05 level, when only the fifteen secondary manufacturing industries are considered. This is to be expected as these workers are primarily concerned with the implementation of the discoveries of scientists and engineers. Their strong association with inno-

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C. Freeman, "Chemical Process Plant: Innovation and the World Market," National Institute Economic Review, 45 (August, 1968), pp. 29-57.

2

Mansfield, The Economics of Technological Change, p. 105.

vation and export performance is probably more a result of their high complementarity with the research workers, under whose direction they work, than to their actually making the advances in knowledge which make new products and processes possible, although they undoubtedly do make contributions in this latter respect as well.

This skill category, as it has been defined here, is extremely heterogeneous, so it may be valuable to examine the contributions of a couple of sub-categories which have been extracted from it. The two sub-categories considered here are statisticians, economists, and programmers, and auditors and accountants. For the former sub-category the rank correlation decreases to .4286 while the linear correlation rises to .6190. For auditors and accountants the rank and linear correlation coefficients, .4679 and .4837, respectively, are both smaller than those for the entire skill category. Auditions and accountants are primarily concerned with compiling data relating to the cost and revenue structure of the firm. This is essential, and the more complete, accurate and sophisticated these accounts are, the more valuable they are. But more important than this to the competitive success of the firm is the use made of this data by the economists, statisticians and programmers in aiding it in planning and rational decision-making. To use new technology to its greatest advantage the firm must determine to what extent it should engage in R & D, in what areas should this R & D be concentrated, which break-throughs are most likely to be economically feasible, and the information provided by these two sub-categories may prove invaluable in making such decisions. Again, for the second skill category and for the two subcategories considered within it, the positive correlations

that occur with respect to exports of secondary manufacturing industries disappear when all manufacturing industries are included.

The third skill category, other professionals, is an even more motley group. The occupations encompassed by it are generally of the service nature—educational, medical, legal, and religious workers and those in the fine arts—and are not as crucially involved in the creation of new products for the manufacturing industries as are the first and second categories of professional workers. Thus their numbers are not correlated with export performance. When considering only the secondary manufacturing industries the coefficients are just slightly positive, and when considering all twenty manufacturing industries the coefficients are slightly negative.

The correlation coefficients of the fourth skill category, managers, are not statistically significant with respect to either the fifteen secondary manufacturing industries or all twenty manufacturing industries. However, in deleting the five primary manufacturing industries the correlation coefficients change from negative to positive and increase substantially in absolute size. Management itself is not likely to create many new products or processes. It is vitally important, however, to the direction the firm follows or not as it is management that determines policy matters. According to Schumpeter, managers play a large role in innovation as opposed to invention.[1] The scientists, engineers, and technicians can only proceed in their attempts to make the firm more competitive if

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[1] C. P. Kindleberger, Foreign Trade and the National Economy, (New Haven: Yale University Press, 1961), p. 85.

instructed to do so by those who possess the ultimate control. It is, in fact, management that decides whether or not these highly skilled personnel required for the creation of new products or processes are to be employed. Thus while there are slightly positive correlation coefficients for managers when considering only the secondary manufacturing industries, the characteristics of management described above and their role in encouraging technological progress are primarily qualitative and are not revealed in the quantitative measures employed here.

The managerial category has been broken-down further to distinguish wage-earning managers only rather than all managers within the labor force. Wage-earning managers account for approximately two-thirds of the managers in the labor force; those managers excluded are the self-employed. Because of the obvious limitations to the size of firm that an entepreneur can manage by himself, the exclusion of self-employed managers given a greater weight to those industries which are generally characterized by larger firms. The correlation coefficients for wage-earning managers again change sign from negative to positive as all twenty manufacturing industries and the fifteen secondary manufacturing industries, respectively, are considered. From being just slightly negative, the coefficients now become much more strongly positive with the linear correlation coefficient being .4661, statistically significant, and the rank correlation coefficient being .4143. The greater number of managers employed reflects an extensive and sophisticated organization making for a more progressive firm. It also suggests that some importance be attached to economies of scale.

For the fifth skill category, machinists, electricians, and tool and die makers, there is no correlation between the extent of their employment and the industry's export performance when all twenty manufacturing industries are considered--one of the coefficients is negative and the other positive, with both fairly close to zero. With respect to the secondary manufacturing industries only, however, there is a weak positive correlation. The workers in this skill category do not initiate basic changes in the product or process as those in the scientific and technical categories do. However, because of their skill and intimate involvement in the production process, they can frequently make minor changes or suggest changes that will lead to improvement in the process or the product. Thus the size of their coefficients is commensurate with their role in technological innovation.

For skill category six, other skilled manual workers, the coefficients with respect to only the secondary manufacturing industries are weaker than those for the fifth skill category, although both coefficients are skill positive. In correlating this skill category with the exports of all the manufacturing industries both the coefficients are again positive, and this time the linear correlation coefficient is statistically significant. Many of the occupations included in this skill category are unique to, or found primarily in, the primary manufacturing industries. Thus, the strength of the Canadian primary manufacturing sector combined with the importance of these occupations in that sector likely accounts for this high positive correlation when primary manufacturing industries are included. It is unlikely that the contribution of other skilled

manual workers to the exports of these industries can be attributed to their importance in technological advance.

For the seventh skill category, clerical and sales workers, there is no correlation when considering all twenty manufacturing industries, one of the coefficients being positive and the other negative. Upon deleting the five primary manufacturing industries, the correlation becomes much more strongly positive, with the linear correlation coefficient becoming statistically significant at the .05 level. As it is not in the nature of sales workers or clerical workers to innovate with respect to either the product or production process, one might initially question whether any meaningfulness can be attached to these results. It should be noted that when only clerical workers are considered the correlations do not change very substantially --for secondary manufacturing industries one of the coefficients is greater and one is reduced, with the linear correlation coefficient remaining statistically significant--so both clerical and sales workers, respectively, are associated with international competitiveness to about the same degree.

The extent to which a firm employs clerical workers is largely a function of its employment of highly skilled professionals--especially the two sub-categories of technicians distinguished above --and managers. As these skill categories are highly correlated with export performance, because of their high complementarity so too will clerical workers be. In regards to sales workers, because of their constant contact with the consumers they are often able to contribute valuable suggestions which will make the product more marketable. It should also be recalled that product differentiation can be an imagin-

ary phenomena insofaras the differences are created in the minds of consumers; it is largely sales workers that are responsible for these persuasive efforts. Sales workers, along with managers, may reflect, at least partially, that very important factor in determining international trade which Wilkinson refers to as aggressiveness.[1]

The correlation coefficients for the final skill category, unskilled and semi-skilled workers, again indicate the relevance of the technological gap theory in explaining Canada's exports of manufactures. Just as it was expected that there would be strong positive correlations for the employment of the highly skilled laborers who are essentially responsible for technological progress, so we expect a negative correlation between the employment of unskilled labor and export performance. For all twenty manufacturing industries both coefficients are slightly negative. However, when the five primary manufacturing industries are excluded the negative correlations become substantially stronger, to the extent that the linear correlation coefficient becomes statistically significant. Those industries which employ semi-skilled and unskilled manpower extensively are not highly competitive internationally.

Considering only the occupational class, laborers within the semi-skilled and unskilled category, the negative correlation for secondary manufacturing industries is considerably weaker. This is because many of the semi-skilled workers who are omitted in considering laborers by themselves are especially prominent in such industries as textiles, knitting mills, and clothing, which are not very strong

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1 Wilkinson, Canada's International Trade, p. 152.

exporting industries for Canada. However, in correlating the occupation of laborers with the exports of all twenty manufacturing industries, the coefficients become positive. In fact, the linear correlation coefficient has the highest absolute value of all the coefficients derived in this study. The high value of this coefficient is due to the inclusion of thefive primary manufacturing industries, for without them the correlations are negative. The negative correlations for the secondary manufacturing industries are consistent with the predictions of the technological gap theory; because unskilled laborers do not contribute to technological progress, they will not be positively associated with export competitiveness. The high positive correlations obtained when including the primary manufacturing industries are also consistent with the previously stated expectation that the technological gap theory, and thus the use of skilled manpower, does not provide a very satisfactory explanation of trade in natural resource oriented commodities. Manpower requirements in the capital intensive natural resource processing industries are primarily for unskilled labor.

In addition to the above correlations which I have been discussing, and which deal exclusively with relating international competitiveness to labor requirements broken-down by skill categories, I have correlated two further, and perhaps more direct, indicators of R & D with export performance, the coefficients for which are given in Table 2. The additional indicators are professional personnel engaged in R & D as a percentage of the total employment of the industry, and R & D expenditures as a percentage of the value of the industry's total sales receipts. The former is similar to the

correlations above as it is in terms of manpower requirements. However, not all scientists and engineers in an industry are involved in R & D; moreover, there are professional personnel from other skill categories involved in R & D. While including more of a cross-section in terms of skills, the laborers included are more homogeneous in terms of function. The latter indicator differs from the other correlations considered in this study as it is the only one not in terms of manpower requirements. Consideration of such an indicator may prove valuable for comparison purposes and in insuring against any potential anomalies inherent in the preceding indicators.

The very high association between new technology and export strength in highly manufactured commodities, and the disappearance of this association when resource--oriented industries are included, is especially evident from these additional indicators of new technology which are considered. All four coefficients when including the primary manufacturing industries are negative, with the linear correlation coefficient for R & D expenditures as a percentage of sales being statistically significant. That the signs of these correlations can reverse themselves to such an extent when the five primary manufacturing industries are included is, again, because these five industries rank among the top exporting industries in Canada's manufacturing sector, but do not engage intensively in R & D. While in terms of professional personnel engaged in R & D as a proportion of total employment some of the primary manufacturing industries (especially Peholeum and coals) exceed that of the secondary manufacturing industries, for R & D expenditures as a percentage of sales

the five primary manufacturing industries occupy the lowest five ranks. With respect to the secondary manufacturing industries only, all of the coefficients are strongly positive, only two of them, however, being statistically significant.[1]

The results achieved using these two indicators of R & D appear to validate the method employed in this study of ascertaining the relevance of new technology to Canadian trade in manufactures by observing the manpower utilization in the manufacturing industries. Consideration of professional personnel engaged in R & D is a percentage of the industry's employment is certainly not superior to considering only scientists and engineers--engaged in R & D or otherwise--as a percentage of the industry's employment.[2] The fact that the coefficients with respect to secondary manufacturing industries do not differ significantly when considering professional personnel engaged in R & D compared to those achieved in considering R & D expenditures as a percentage of sales provides strong support as to the appropriateness of labor skills as an indicator of new technology.

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1 Correlations must be numerically higher to be statistically significant for these indicators as there are fewer industries being considered. There is R & D data given for only fifteen manufacturing industries in total as tobacco, leather, clothing, knitting, mills and miscellaneous have been combined, and the printing and publishing industry has been omitted.

2 Gruber, Mehta, and Vernon, "The R and D Factor in International Trade," p. 29, show that those industries utilizing scientists and engineers in R & D to the greatest extent also utilize them to the greatest extent in production.

CONCLUSION

The empirical results derived with respect to Canadian manufactured exports in Chapter Three do, as already stated in Chapter Four, demonstrate the relevance of new technology in Canada's exports of manufactured commodities. The importance of new technology was gauged by the employment of skilled manpower by an industry. The procedure of looking at an industry's inputs rather than its outputs is legitimized by the fact that "new knowledge must exist in the minds of men before it can be embodied in new skills, new machinery, new products and new processes."[1]

The Royal Commission on Canada's Economic Prospects stated that

> it is surprising that so little systematic information exists on Canada's most precious resource--the skills, capacities and creativeness of her people. It is on the skills of the working population, particularly the more highly trained elements in it, that the material and cultural progress of the nation depends.[2]

It is hoped that the above findings, demonstrating the systematic relations between labor skills and international trade, can be considered a contribution to the type of information sought by this Royal Commission.

In recent analyses of the economic growth of various countries it has been found that human skills have constituted a very signifi-

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1 Economic Council of Canada, Fifth Annual Review: The Challenge of Growth and Change, (Ottawa: Queen's Printer, 1968), p. 44.

2 Royal Commission on Canada's Economic Prospects, Skilled and Professional Manpower in Canada, 1943 - 1965, Economics and Research Branch, Department of Labor (Ottawa: Queen's Printer, 1957) p. 101.

cant source of economic growth. Aukrust found that of the 3.4 per cent annual rate of economic growth in Norway over the period 1948-55, 0.46 per cent resulted from increased employment, 1.12 per cent from increased capital, and 1.81 per cent from the expanding contribution of the 'human factor' which he defined as "organization, professional skills and technical knowledge."[1] Kendrick has estimated that over 75 per cent of the increase in output per man hour since 1900 in the United States was the result of technical progress.[2] In another analysis of the economic growth of the United States, Denison estimated that 40 per cent of the annual per capita growth rate of 1.7 per cent from 1929-57 could be attributed to increased education.[3] Bertram, in applying the Denison technique in analyzing Canada's economic growth, found that educational improvements accounted for approximately 25 per cent of the increase

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1 Cited in B. R. Williams, "Investment and Technology in Growth," Manchester School of Economic and Social Studies, 32 (January, 1964) p. 59.

2 J. W. Kendrick, Productivity Trends in the United States, A Study by the National Bureau of Economic Research, New York (Princeton: Princeton University Press, 1961).

3 E. F. Denison, The Sources of Economic Growth in the United States and the Alternatives Before Us, (New York: Committee for Economic Development, 1962).

in productivity per employed person from 1911 - 61.[1, 2]

These studies all attest to the importance of increasing skills, knowledge, and technology in the economic growth of nations. The technological gap theory of trade is based on differences in the rate of technological advance among nations. Just as the application of new technology to the production process is a vital element in determining the rate of economic progress of a nation, so too it is vital in determining the competitive position of this nation with respect to other nations.

The consideration of new technology in the context of international trade augments the case for giving some priority to the pursuit of technological advance as a national policy objective. The empirical findings presented above with respect to Canada's exports of secondary manufactures suggest that greater application of new technology by Canadian industries could contribute to Canada's economic growth and the enhancement of her standards of living not only by providing superior products--or similar products at lower prices--to Canadians, but also by allowing Canadian industry,

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1 Economic Council of Canada, The Contribution of Education to Economic Growth, Staff Study No. 12 by G. Bertram, (Ottawa: Queen's Printer, 1965).

2 That Bertram's estimate of the contribution of education to Canada's economic growth was considerably lower than Denison's estimate for the United States is likely an important factor in explaining why the correlations between indicators of technological change and trade performance obtained for Canada are lower than those obtained by Keesing and by Gruber, Mehta, and Vernon for the United States.

and the Canadian economy, to gain further income by acquiring international markets for these products. Having found that new technology is relevant to Canada's ability to compete in international markets for secondary manufactures, it is not within the scope of this study to furnish the precise policies to be pursued in promoting technological advance. The answers to such questions can be adequately provided only through much more specific and intensive studies than can be provided here. Nevertheless, some general implications which are suggested by the above analysis will be mentioned.

It is implicit in the above that the market mechanism alone does not provide the necessary or desirable rate of technological advance. Apart from the high risks involved for a firm attempting to innovate, because of the external economies generated by technological advance its benefit to society generally exceeds that to the producer of it. Thus if the socially desirable rate of technological advance is to occur, it must receive support from government or other non-profit agencies. Another area in which government has become involved in technological advance is through the protection, and thereby inducement, of the patent system whereby innovators are given greater assurance of adequate compensation for their efforts.

Regardless of how important one considers R & D to be in promoting economic growth, and of what priority is to be given economic growth as a national policy, a government must carefully allocate its support of R & D. A country need not spend greater amounts, nor even as great amounts, than other countries on R & D to achieve success in international markets, as an efficient allocation of limited R & D expenditures can permit intra-industry specialization, allowing

these highly-specialized industries to be internationally competitive. As not all industries are equally amenable to technological innovation, to support R & D indiscriminately in all industries when funds for R & D expenditures are limited would, obviously, be a highly irresponsible policy. In this respect the Canadian government is to be commended for its establishment, as reported in the Economic Council's Fifth Annual Review, of a Science Council to advise

> The Government on how best to use science in the solution of economic and social problems and to give guidance on priorities in those areas of scientific and technological research that would contribute most effectively to the achievement of national goals.[1]

It has also established a Science Secretariat to aid in the co-ordinating of information, thereby facilitating the flow of communication between and within industries and other research--connected agencies which is very essential for efficiency in scientific and technological advance.

Grabowski's regression analysis showed that interfirm differences in technology, product diversification, and the availability of funds were all significant in explaining the research intensity of firms in the chemicals, drugs, and petroleum refining industries.[2] The latter variable suggests that the level of R & D expenditures by a firm will be sensitive to government policies which effect the finan-

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1 Economic Council of Canada, Fifth Annual Review, p. 32.

2 H. Grabowski, "The Determinants of Industrial Research and Development: A Case Study of the Chemical, Drug, and Petroleum Industries," Journal of Political Economy, 76 (March/April, 1968) pp. 292-306.

cial incentives confronting the firm. Rather than relying entirely on direct government subsidies, Canada has made some attempts to induce technological advance through this type of fiscal policy. In 1967 the Industrial Research and Development Incentives Act was passed in Canada, under which

> Canadian corporations are entitled to apply to the Department (of Industry) for a cash grant or for a credit against their federal income tax liabilities amounting to 25 per cent of:
>
> 1. all their capital expenditures (for the acquisition of fixed assets other than land) for scientific research and development in Canada; and
>
> 2. the increase in their current expenditures in Canada for scientific research and development over the average of such expenditures in the preceding five years.[1]

In view of the strong positive influence of technological advance on a nation's international competitiveness, the appropriateness of pursuing prices and incomes policies in combatting trade deficits, specifically with respect to Britain's present policies, has been questioned.[2] Rather than attempting to prevent the economy from operating at full capacity so that least-efficient, high-cost resources need not be utilized, A. Keynes has suggested that the pressure of demand can induce technological advance in two ways: it may induce static economies of scale to occur and it may enhance

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[1] Canada Department of Industry, Annual Review 1967, (Ottawa: Queen's Printer, 1968), p. 14.

[2] A. Keynes, "Competition by Innovation," District Bank Review, 166 (June, 1968), pp. 33-46.

the profitability of investment thus making possible the application of new technology. Prices and incomes policies, which are based on the classical theories of international trade, amy be less effective in fostering a more internationally competitive economy than the inducements inherent in a dynamic, expanding economy.

The possibilities of trade liberalization and the establishment of regional trading blocs also appear much more attractive in light of the contribution of new technology to international trade.[1] Such schemes will provide the larger markets necessary for the expansion of trade and greater specialization in production, increasing the possibilities for technological advance. These prospects are especially attractive to countries such as Canada which have a limited domestic market.

While in the short-run the most effective technological effort must be achieved through efficiently allocating the available resources, in the long-run government can extend our capabilities for advancing technology by creating an educational system which will produce more qualified personnel, so that more good minds can be devoted to cultivating new technology. Thus, in the long-run, education policies which ensure the least possible wastage of

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[1] G. C. Bjork, "NAFTA: Technology, Trade, Growth," Columbia Journal of World Business, 3 (September-October, 1968), pp. 61-68.

human resources are the most important instruments available to government in promoting technological advance.

As a closing note, while the positive role of technological advance has been emphasized here, there are also many costs involved and socio-economic problems created by technological change. The very existence of mankind is continually threatened by the creation of, and the steadily increasing destructive ability due to technological advance in, nuclear weapons. Perhaps as potentially explosive as the nuclear arms problem is the growing gap between the rich nations and the poor nations of the world, as the benefits from expanding technology accrue primarily to the former group of nations whose demonstration of concern for sharing these benefits has not been very apparent. There are victims in the domestic economy of the dissuption caused by technological change---firms and industries whose competitive positions have deteriorated and employees whose jobs have become antiquated. Advancing technology and increasing industrialization have led to a greater concentration of population in urban centres, necessitating extensive application of public policy to provide the opportunity for all citizens to enjoy the 'good life'. While it is often said that our ability in advancing technology exceeds our capacity to make the necessary political, economic, social, and institutional adaptations, our ability in this latter respect could perhaps be improved by altering our priorities.

APPENDIX A

Labor Skill Categories		Occupation Code Numbers From Occupational Classification Manual, Census of Canada, 1961
1	Scientists and Engineers	101 - 129
11	Technicians and Draftsmen	181 - 188
111	Other Professional	131 - 176, 191 - 199
1V	Managers	001 - 010
V	Machinists, electricians, and tool and die makers	801 - 819,831 - 839
V1	Other skilled manual workers	751 - 793, 821 - 829, 841 - 869
V11	Clerical and sales workers	201 - 339
V111	Unskilled and Semi-skilled workers	401 - 749, 871 - 980
1.	Managers (wage earning)	001 - 010
2.	Clerical workers	201 - 249
3.	Laborers	920
4.	Statisticians, economists, and programmers	184 - 187
5.	Auditors and accountants	188
6.	Engineers	101 - 109
7.	Scientists	111 - 129

APPENDIX B

	S.I.C.	S.I.T.C.
1.	Food and Beverage Industries	011-024, 031.2-032, 046-048, 052-053, 054.6-055, 061.2,5,9, 062, 071.3, 072.2-074, 081-112, 41, 42.
2.	Tobacco Products Industries	122
3.	Rubber Industries	62, 841.6
4.	Leather Industries	61 (excl. 613), 83,85
5.	Textile Industries	65 (excl. 653.7), 266
6.	Knitting Mills	653.7, 841.4
7.	Clothing Industries	84 (excl. 841.4,6)
8.	Wood Industries	243, 63
9.	Furniture and Fixture Industries	82
10.	Paper and Allied Industries	25, 64
11.	Printing, Publishing, and Allied Industries	892
12.	Primary Metal Industries	284, 67 (excl. 675), 68 (excl. 681, 688)
13.	Metal Fabricating Industries	675, 69 (excl. 697.1), 711.1, 812.1,3
14.	Machinery Industries	71 (excl. 711.1,4, 719.4)
15.	Transportation Equipment Industries	711.4, 73, 894.1
16.	Electrical Products Industries	697.1, 719.4, 72, 812.4
17.	Non-Metallic Mineral Products Industries	66 (excl. 667), 812.2
18.	Petroleum and Coal Products Industries	321.5-8, 332, 341.2
19.	Chemical and Chemical Products Industries	5
20.	Miscellaneous Manufacturing Industries	613, 667, 86, 89 (excl.894.1,892)

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